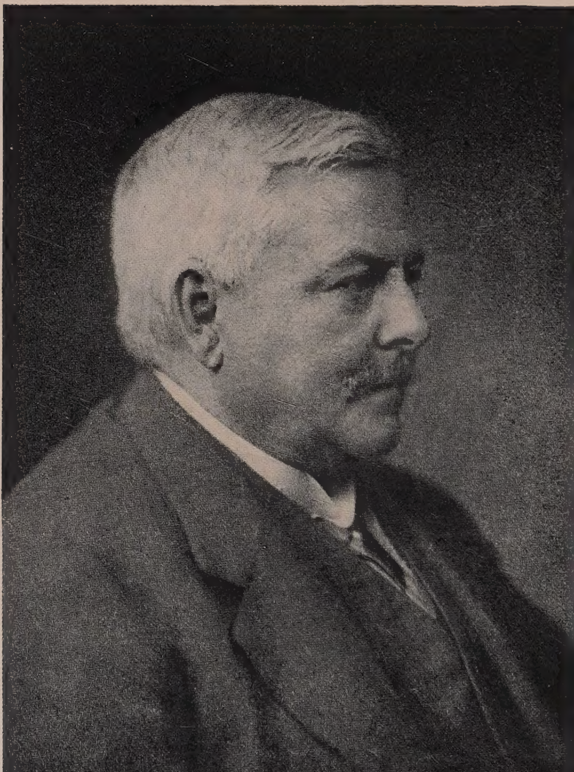
SHIPLEY

Hunting under the microscope.

# HUNTING UNDER THE MICROSCOPE



# HUNTING UNDER THE MICROSCOPE

*by*

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# INTRODUCTION

The late Sir Arthur Shipley had more than a a wide knowledge of Biology and its recent advances; he had a singular gift for picking out the essential principles and for explaining them to the layman. There are few books from which the non-scientific man or the schoolboy endowed with curiosity and no scientific knowledge can learn so much of the nature of living things as from Sir Arthur's previous volume, *Life*; and his work is distinguished by the delightful humour with which he can drive his points home.

In this book is collected a series of articles, previously published in *Discovery*, on microscopic pond-life. Sir Arthur had begun to get the book ready for publication, and wrote to ask me to help him in the revision. Unhappily, he died before he had got far with the arrangement of the articles, and upon me has devolved the duty of seeing that the arrangement is completed as he would have wished. This is not an easy task, but I have some experience of his methods through helping him while he was engaged on his book on *Life*. The articles have, of course, been left unchanged as far as possible. I have, however, inserted in the text one or two sentences in explanation of

zoological terms, the meanings of which are not clear to the non-scientific reader (*e.g.*, on Tracheae, p. 136). I have done this instead of adding footnotes because these break the reader's continuity of thought, and because the author would undoubtedly have himself inserted such explanations.

After the first chapter on Suspended Animation, the successive chapters are arranged according to zoological sequence, going from the simplest unicellular to the more complex multicellular animals. This has the additional advantage that it also indicates roughly a sequence in size, the organisms considered in Chaps. III. to VII. requiring a low-power microscope for their study, whereas those dealt with in Chaps. VIII. to XIV. require only a hand magnifying lens, such as can be bought for a few shillings at any optician's. The last chapter is a review of Sir Ronald Ross's great book on Malaria, and follows naturally the chapter on mosquitoes. It gives some idea of the great benefits to humanity which have resulted from the study of fresh-water organisms.

As one of the chief objects of the book is to encourage people to go hunting among ponds and ditches for their own amusement, a few hints on where to find the organisms will not be amiss.

Spring and summer are the best times for collecting pond animals. These tend to disappear during the colder months, but even in winter mud collected from likely places will yield a good supply of organisms, especially if kept in a warm

room. The following Table will give some idea of where to find the various species mentioned :

| Organism. | Locality. |
| --- | --- |
| Amoeba. | Small ponds and pools, shallow water with decaying vegetation but not stagnant ; clear ditches where there is a brown scum on the bottom, due to microscopic plants (Diatoms). |
| Arcella, Gromia, Difflugia. | Ponds and ditches with a little water-weed, but not stagnant. Moorland pools. |
| Paramoecium, Vorticella, and other Ciliates. | Vorticella often found in quantities on filaments of weeds in fairly clean ponds. Paramoecium and allied ciliates in almost any ponds and pools, especially if somewhat stagnant or in the neighbourhood of any decaying plant or animal matter. Prolific cultures of ciliates can be produced from infusions of hay or other organic matter, in tap-water, especially if a little pond mud is added. |
| Euglena, and other Flagellates. | Ponds and ditches fairly free from weed. Water-butts ; in these the water often becomes green from teeming millions of Euglena and its allies. |
| Pandorina, Eudorina, and Volvox. | Ponds and ditches with fairly clean water, especially in fields frequented by cattle. |
| Hydra. | Clean ponds and sluggish streams. If water-weed from these is left in a glass jar, Hydra (if present) will in an hour or two wander on to the sides. |

| Organism. | Locality. |
|---|---|
| Rotifers. | Fairly clean ponds, *temporary* pools, water-butts. |
| Water-fleas, Cyclops. | Lakes, ponds, and moorland pools of all kinds, including temporary pools. |
| Ostracods. | Distribution as above, especially where there is some decaying matter (*e.g.* dead leaves) on which to feed. |
| Water-mites. | Fairly clean ponds and ditches, particularly those containing water-snails. |
| Mosquito and Gnat larvae. | Any water-butt. |

When hunting for Amoeba, and allied forms like Arcella and Gromia, an excellent plan is to allow freshly stirred water and mud to settle on the bottom of a glass dish. (The kind known as Petri-dishes, which are used for making cultures of bacteria, are very convenient for this purpose and for all study of microscopic animals. They are circular glass dishes, 2 or 3 inches in diameter, with flat bottoms and sides about $\frac{1}{3}$ of an inch high.) The dish should be filled to the depth of about $\frac{1}{3}$ of an inch with mud and scrapings which are suspected to contain Amoebae, and allowed to settle for five minutes. After that the mud should be gently shaken and poured off. This will wash away most of the debris, but Amoeba and his allies will be found still sticking to the bottom of the dish when it is refilled with water and examined under the microscope. An excellent

way of studying these animals is to cultivate them. This can be done conveniently by putting pond-water and mud into glass jars (those in which tongues are sold do well) and adding to this a few grains of well-boiled wheat. Bacteria live on the wheat, and Amoebae, and other unicellular animals, live on the bacteria. A full account of this method of culture will be found in an article by M. Taylor, entitled " Aquarium Cultures for Biological Teaching ", in the periodical *Nature*, 1920, vol. 105, p. 232.

People who have the advantage of living by the seaside will be able to get enormous numbers of interesting microscopic forms closely allied to those described in this book, by taking scrapings from rock-pools, the surface of sand, the piles of old piers, and so on. Even if there is not much to be found on immediate examination, micro-organisms rapidly develop if the scrapings are left to stand in a small bowl. Boiled wheat is also admirable for the culture of marine micro-organisms.

Finally, a word about the use of the microscope. There are many popular hand-books which give full information about the theory of the microscope and its uses, in fairly simple language (*e.g.*, *The Microscope*, by Conrad Beck. R. J. Beck & Co., London.). A few general hints need only be given here.

Almost all the organisms mentioned in this book can be examined with ease under comparatively low-power lenses. Suitable lenses are a No. 4 eye-piece,

and an objective of $\frac{2}{3}$ inch focal length, or even of $1\frac{1}{2}$ inches focal length. It is a mistake frequently made by those beginning the study of micro-organisms to try to use the highest possible magnification. High-power lenses are not easy to handle till experience has been gained with low powers. Low powers give delightful results, even in the hands of one who has never used a microscope before. It needs no great magnification of lenses to make visible to the investigator a world of strange and beautiful animals which his naked eye cannot perceive.

It is important, when examining samples of pond-water for organisms, to keep the microscope vertically upright. This makes it possible to have a flat glass dish filled with water for examination on the microscope stage, with no risk of spilling. For picking out individual animals, glass fountain-pen fillers are useful, and should be drawn out to a very fine point, varying from $\frac{1}{10}$ to $\frac{1}{25}$ of an inch. A chemist will do this.

These are brief hints, but it is hoped they will prove helpful. And any person who is inspired by this book to go himself "hunting with a microscope" will not regret it, but will always be glad of his introduction to a pursuit of such absorbing interest.

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# CONTENTS

# ILLUSTRATIONS

CHAPTER I

# SUSPENDED ANIMATION—I

## TARDIGRADES, ROTIFERS, AND NEMATODES

IN an article I wrote some year or two ago, dealing with Life, it was pointed out that Life was difficult, if not impossible, to define, but that living organisms have certain definite attributes such as breathing, feeding, moving, reproducing, and so on. There are, however, times when these functions are suspended.

If we collect some of the debris in gutters, amongst moss, or in holes in trees, or in ditches, and examine it under a microscope, we may be lucky enough to come across one or two specimens of a group of very small animals known as TARDIGRADA. These little creatures are minute, and in some cases transparent. Zoologically they are remotely connected with the great group of spiders, but they have no near relatives. They are provided with four pairs of legs ending in claws, and their slow and deliberate movements have earned them the name of Bear Animalcules. They live obscure and hidden lives, "remote from the world", as Cecil Rhodes described the lives of the Dons at Oxford. Of animals that consist of many

cells, they are amongst the smallest, averaging one-third of a millimetre to one millimetre in length. So obscure are they that they are usually overlooked, yet Max Schultze asserts that they are, without doubt, the most widely distributed of all animals that are segmented.

The TARDIGRADA possess many features of interest. Some species look like dear little sucking-pigs in plate armour. In their natural state —in a damp atmosphere—they live, and move,

FIG. 1.—A Tardigrade.
Highly magnified. (From Doyère.)

and have their being, like any other animals; but if their surroundings dry up, or if one be removed and placed upon a slide and allowed to dry, then will their movements gradually slacken until they entirely cease. The body begins slowly but steadily to shrink. The outline and form are lost. The skin becomes wrinkled and folded, and in a short time it assumes the appearance of a much-weathered grain of sand, and all vital activities are suspended, or at any rate reduced to an unascertainable minimum. In this dried-up con-

dition tardigrades may remain for many years without undergoing any visible change. If, however, they be moistened with water, the steps the animal underwent when drying up are retraced. The "grain of sand" begins slowly to swell; the wrinkles disappear; gradually a plump little animal—for they are so plump that you feel inclined to pat them, only they are too small—swells up; the legs stretch out; and slowly the animal assumes its normal shape. For a time it remains quiet, and then it begins slowly and feebly to move about, and after a period which varies from a quarter of an hour to several hours, according to the time its life has been suspended, the little animal crawls away "on its lawful occasions".

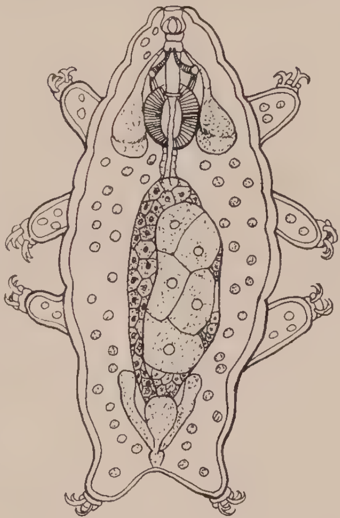

FIG. 2.—A Tardigrade, showing internal organs.

In the same sort of position, in gutters, amongst moss, are another group of animals known as the ROTIFERA or Wheel Animalcules. These are creatures of singular beauty which bear on their

heads a number of cilia whose rhythmic flickering produces an appearance of a wheel going round.

Fig. 3.—A Tardigrade, dried, in a state of apparent death.

More than 200 years ago Leeuwenhoek recorded the fact that these little microscopic animals were also capable of drying up, and resuming their normal activities when moisture is again applied. As long ago as 1774–5 Mr. Baker, in a letter addressed to the President of the Royal Society, stated that the animal described

can, however, continue many Months out of Water, and dry as Dust; in which Condition its Shape is Globular, its Bigness exceeds not a Grain of Sand, and no Signs of Life appear. Notwithstanding, being put into Water, in the Space of Half an Hour a languid Motion begins, the Globule turns itself about, lengthens by slow Degrees, becomes in the Form of a *lively Maggot*, and most commonly in a few Minutes afterwards puts out its Wheels, and swims vigorously through the Water in Search of Food: or else, fixing by its Tail, works them in such a Manner as to bring its Food to it. But sometimes it will remain a long While in the Maggot Form and not shew its Wheels at all.

Still another group of animals very widely distributed are the threadworms or Nematodes. Some of these live freely in the earth or water, but

a great number of them are parasitic or live inside the bodies of other animals or plants. Amongst

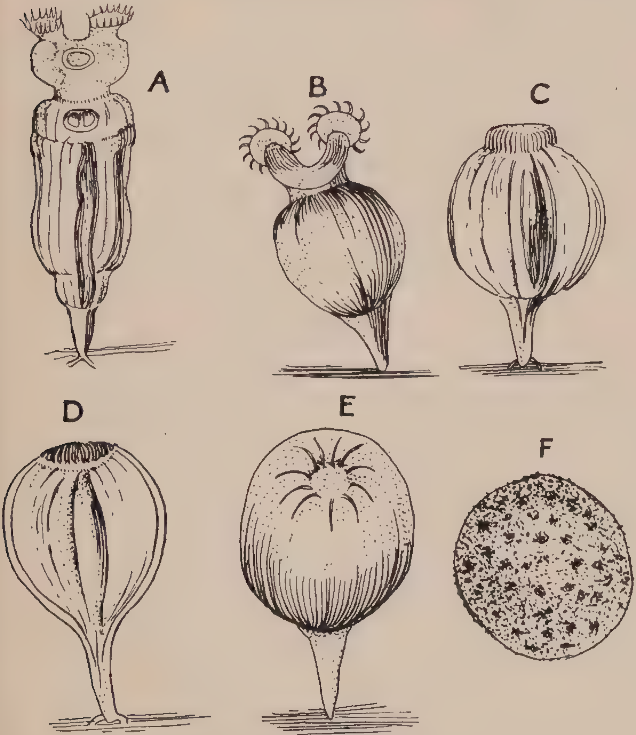


FIG. 4.—A, B, C, D, E, a Wheel-bearing animal, or Rotifer, in various states of activity ; F, in a state of suspended animation.
Highly magnified. (After Baker.)

the parasites of the latter is the threadworm which causes the ear-cockles in corn. These

climate; and this in a manner that can scarcely be called hibernation, for they frequently take up the position of repose when the weather is still warm, and on the other hand recommence their activity in the spring at a very early period. This phenomenon may frequently be noticed in the tortoise-shell butterfly; it is as if the creature knew that, however warm it may be in the autumn, there will be no more growth of food for its young, and that in the spring vegetation is sure to be forthcoming. . . . It should, however, be recollected that many larvae of butterflies hibernate as young larvae after hatching, and, sometimes, without taking any food.

As is well known, the activities of the inhabitants of the beehive, although lowered and to some extent in suspense, are still carried on. It is quite different with wasps and bumble-bees. The colony dies down and disappears; only the queen survives, and this she does in a motionless, inactive condition, hidden away in a crack in a tree or in a ditch. The majority of insects pass through the winter in a pupa or chrysalis stage, hidden away under leaves or buried in the ground. But as pupae are generally inactive and motionless, the hibernation is not a very obvious alteration in their normal habits. Many beetles and several species of dragon-fly hibernate during the winter in a larval state, and as the former are very often found embedded in burrows in trees they do not require a special winter home. The larvae of the dragon-flies and of the may-flies hide themselves in the side or muddy bottom of their native pools.

Towards the close of autumn the whole insect world in temperate climates is on the move. Like the executive of the Government at Washington during the time of the Presidential election with the parties changing sides, they are all "making for cover". Lady-birds, field-bugs, and flies have retired into their winter-quarters well before the first frost has occurred; very often on the hottest autumn days.

To those who are on the outlook, the coming together of numerous species of beetle on quiet autumn days is as striking as the assemblage of swallows before they take their autumn flight for sunnier climes. Kirby recalls that whilst

> walking on the banks of the Humber on the 14th of October about noon—the day bright, calm, and deliciously mild, Fahrenheit's thermometer 58° in the shade—my attention was first attracted by the pathways swarming with numerous species of rove-beetles (*Staphylinus*, *Oxytelus*, *Aleochara*, etc.), which kept incessantly alighting, and hurrying about in every direction. On further examination I found a similar assemblage, with the addition of multitudes of other beetles, *Halticae*, *Nitidulae*, *Rhynchophora*, *Cryptophagi*, etc., on every post and rail in my walk, as well as on a wall in the neighbourhood; and on removing the decaying mortar and bark, I found that some had already taken up their abode in holes, from the situation, with their antennae folded, evidently meant for winter-quarters.

The aphis passes the winter both in the egg and in the perfect state. All these insects fall into a

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The aphis passes the winter both in the egg and in the perfect state. All these insects fall into a

coma. At first they are but partially benumbed, and when touched are still capable of moving their limbs. Soon, however, the insect practically ceases to breathe, to feed, or to move. The muscles lose their irritability and they have all the appearance of being dead. Whereas in the case of the Rotifera and Tardigrada the suspension of life is due to the drying up of their watery surroundings, the hibernation of insects and snails, and—as we shall see later—of various forms of vertebrate animal, is due mainly to the onset of winter. It is a seasonal occurrence, though in many cases we shall notice that in the tropics, where animals retreat during the hotter months (aestivation), the hotter months coincide in time with the drying up of the surroundings.

CHAPTER II

# SUSPENDED ANIMATION—II

## FISH

A VERY considerable number of vertebrates (animals with backbones), for instance the *Carp*, bury themselves in mud during the winter and live with life in abeyance. This may possibly account for the great age to which carp live, namely from fifty to one hundred years or even longer. They are very prolific, and like all long-lived fish they grow slowly, but attain a considerable size, running up to 50 lb. The carp is really a native of Persia and China, and was introduced into Europe in the middle of the thirteenth century. It was known in England towards the close of the fifteenth century.

At the very top of the fishes are animals which have almost turned into AMPHIBIA, for they have lungs as well as gills. One of these, *Protopterus*, lives in the western half of Africa and spreads through the whole of the tropical regions of that country. During the dry season, which in this part of the world is in the summer, these animals, living in shallow water which periodically dries up, retire into the mud and make a kind of clay ball

which is lined and held together by a secretion of slime. These clay balls, if dug up unbroken, can be transported about the world, and if placed in tepid water, the capsule gradually dissolves and the fish emerges. Another two-lunged fish of the same family, *Lepidosiren*, occurs in tropical America, and it also is stated to make mud capsules. As these fish mostly go into retreat during the summer, they are said to aestivate and not to hibernate.

The Carp family, as has been already mentioned, hibernates, but not completely, and the same is true of certain eels. None of these fish fall into a complete state of coma, as reptiles and mammals are apt to do, but all their living functions are reduced and lowered. They cease to feed, they cease to look for food, and retire into holes and crannies where they are sheltered from their enemies. In India certain fishes can survive embedded in the mud for several years, and ponds which have been dried up for some time become rapidly crowded with fish when water again enters them.

### Amphibia

When we leave fishes and come to the *Amphibia*, the frogs and the newts—animals which live part of their life in the water and part on land—we find that they are creatures which can live for many months without food. In the cooler parts of the world many of these hibernate in the mud; in hot climates they take up a similar habitat, but

that only during the dry season. They can endure a surprising amount of cold, at any rate those of the temperate region, but they will not survive being frozen hard as the carp will. Frogs hibernate generally in masses together at the bottom of ponds, but if reached by prolonged frosts during exceptionally severe weather they succumb. This is especially true of the younger animals, the older being more experienced and more successful in finding safe retreats. Frogs which have just hibernated can stand complete immersion under water for eight times the period which will suffice to drown them during the breeding season. The many and repeated accounts of frogs and toads having been buried for centuries in holes in the solid rock and in coal have never been substantiated and may be dismissed as fables.

## Reptiles

Amongst the *Reptilia* anyone who has ever kept a land-tortoise knows that it disappears underground during the winter, and fresh-water tortoises hide away in the banks or at the bottoms of rivers. Snakes and lizards disappear into holes in trees or under stones and dry leaves.

The terrapin, so beloved by epicures in the Southern United States, dig themselves into holes during the winter months, and they do not come out until the spring is well advanced. The so-called box-tortoise, a domestic pet in the United States, becomes very tame ; but it must be allowed

to hibernate. If kept in a warm house they become fretful in the autumn, refuse all food and drink, and are liable to die unless they can find a cool place to hide away in and sleep for months. If left out-of-doors they burrow into the ground or sometimes hide under a heap of rubbish well out of the reach of the frost. But a warm April day brings them back to life, and then their first requirement is a little drink. The Greek and Moorish tortoises, which are sold from barrows in our streets, and are kept as garden pets, also require to hibernate, and if lured from their winter homes by exceptionally warm days in the early spring, are likely to suffer in health should a cold spell set in, for they are very much less hardy than before they entered into retreat. The gigantic land-tortoises from the Aldabra atoll bury themselves for at least half a year.

Another group of reptiles, the crocodile and alligator, in the tropics aestivate in the hardened mud; they have been known to exist in this state of seclusion for a whole year without food. Tennant, in his well-known work on Ceylon, recalls the story of an officer who, when camping out one night, was disturbed by a curious movement underneath his bed; the movement was explained in the morning by the emergence of a crocodile. Crocodiles will also hide away in mud at the approach of danger, and like many another animal they feign death.

We have mentioned above that snakes and lizards frequently hide away during the colder

months, and it is a curious fact that, should a viper be awakened during its winter sleep, its bite is said to be harmless. Whether this is so or not requires confirmation, but I do not propose to try the experiment myself.

## Birds

The naturalists of the eighteenth century, even the gifted Gilbert White, believed that certain birds hibernated. The disappearance of the swallow each autumn, of the corncrake, nightingale, cuckoo, etc., was by them accounted for by the idea that these birds hid away sometimes under water, and rested during the colder months. This view has now been entirely given up, as it is now known that they retire to warmer climates during the winter.

## Mammals

Amongst mammals many species hibernate in the temperate and colder regions of the world during the winter. The well-known European hedgehogs, often kept as pets in the gardens of Great Britain, are the largest of our native Insectivores and they hibernate completely. Unlike the squirrel, they store no food, but retire into a bed of moss or leaves and roll themselves up into a ball with all their prickles outside, and remain in seclusion until the spring warmth revivifies them.

There is another curious little Insectivore known as the *Tenrec*, an animal possibly allied to the marsupials of Australia and America. They are generally found in the mountains of Madagascar, and during the colder seasons of the year hibernate for a long period. They fatten themselves up during the spring, and in this condition are much sought after by natives as an article of food. About May or June they retire into deep burrows in the ground and do not re-emerge until the following Christmas.

The common racoon, which is confined to America, is particularly common in the Adirondacks. It hibernates during the severest part of the winter; as Dr. Merriam tells us, "retiring to his nest rather early and appearing again in February or March according to the earliness or lateness of the season".

The same author records that the black bear also hibernates, although its torpor is not deep, and the time of entering upon the winter repose depends upon the severity of the season and the amount of food-supply. The males will remain active in any weather, so long as they can find abundance of food. The female is, however, compelled to seek shelter sooner on account of her prospective family. The winter den of a black bear is generally a partial excavation under the upturned roots of a fallen tree, or beneath a pile of logs, with perhaps a few bushes and leaves scraped together by way of a bed, while to the first snowstorm is left the task of completing the roof and filling the remaining chinks. Not unfrequently the

den is a great hole or cave dug into the side of a knoll, and generally under some standing tree, whose roots serve as side-posts to the entrance. The amount of labour bestowed upon it depends upon the length of time the bear expects to hibernate. If the prospects point towards a severe winter, and there is a scarcity of food, they "den" early and take pains to make a comfortable nest; but when they stay out late, and then "den" in a hurry, they do not take the trouble to fix up their nests at all. At such times they simply crawl into any convenient shelter without gathering so much as a branch of moss to soften their beds. Snow completes the covering, and as their breath condenses and freezes an icy wall begins to form, and increases in thickness and extent day by day till they are soon unable to escape, even if they would, and are obliged to remain in this icy cell till liberated by the sun in April or May.

Although in the south the grizzly bear remains active throughout the winter, in the northern part of its range it hibernates. When during the spring it emerges, it has a habit of standing upright against a tree and scoring the bark with its claws. As it usually stands on a base of four or five feet of hardened snow, the height of its clawings must not be taken as representing the length of the animal, though sportsmen who tell bear stories very often do so.

But perhaps the best known among the hibernating animals are found amongst rodents. Squirrels, as we have indicated above, are but partial hibernators. In temperate climates they

retire during the winter into hollows of trees. They bury their stores of nuts, or other food, just beneath the surface of the ground in various caches in the woods, and from time to time awake from their winter sleep to feed.

The chipmunk, as Dr. Merriam tells us, begins to hoard up large stores of food in the autumn, and being the least hardy of the American squirrels, commonly goes into winter-quarters at the beginning of November, not appearing again until the early thaws of February tempt him out.

The marmots of Europe and Asia also hibernate, the Alpine species making large burrows with a single entrance. The burrows end in a large chamber lined with grass, and here, coiled away from the cold, some ten to fifteen marmots may be found clustered together.

One of the commonest children's pets in Great Britain is the dormouse, and as readers of *Alice in Wonderland* will remember, it is a profound sleeper. The dormouse accumulates much fat at the approach of winter, but a warm day will bring it out to eat some of its accumulated store of fat, acorns, beech-nuts, beech-mast, or corn.

One more example. A certain little lemur confined to Madagascar retires into torpidity during the southern winter or dry season. Before retirement, however, it accumulates an immense quantity of fat in certain parts of its body, notably in the tail, which recalls the appendage of the well-known fat-tailed sheep of the Cape,

or Middle East. By the time the lemur emerges its tail has resumed its normal dimensions.

We have seen there is a certain progressiveness in hibernation: some animals come to life during the winter and feed, others remain immovable for months. But in all, the vital processes are much weakened and diminished. Feeding and movement are at an end, the heart-beat is limp and the breathing imperceptible. In those animals that hibernate most thoroughly, life is sustained by their absorbing their own fat.

## Human Beings

We have said that one of the attributes of living organisms is that they perform certain actions rhythmically at stated periods. One of the most striking of these rhythms is sleep. We have also seen that this sleep, in the case of certain animals, may be not a matter of day and night, but may be prolonged throughout the winter, or in the tropics throughout the summer. There are many cases in human beings where sleep is prolonged into a trance, and for the most part these trances are not within the control of the sleeper. A trance is a sleep-like state which comes spontaneously, and is independent of any poisons, though of course certain poisons produce profound sleep. It is very difficult to arouse a person from a trance. People subject to them are seldom in perfect health. Very often they are slightly hysterical, and in other cases they are anaemic.

As a rule a trance sets in quite suddenly. There is a case of a girl going into a room by herself and being shortly afterwards found in a state of coma which lasted thirty-eight hours. In another case a young woman went upstairs to change her dress, and was found in a state of trance on her bed, which lasted for fourteen days. But the most interesting factor about trances is that sometimes they can be produced at the will of the sufferer. In India, where mystery and magic are very prevalent, it has for a long time been believed that certain holy men called "fakirs", who live a life of privation and often of self-inflicted torture, have the power of voluntarily placing themselves in a state of suspended animation, which lasts for varying periods. At the end of each period they return to life unchanged and undisturbed. It is a common tale of Indian travellers.

Verworn has recorded an instance quoted from Baird, one of the earliest writers on hypnotism, in the following lines :

At the palace of Runjeet Singh, in a square building which had in the middle a closed room, a fakir, who had voluntarily put himself into a lifeless condition, had been sewed up in a sack and walled in, the single door of the room having been sealed with the private seal of Runjeet Singh. (To judge from the account, the air, as in all such cases, was not absolutely excluded.) In order to exclude all fraud, Runjeet Singh, who was not himself a believer in the wonderful power of the fakirs, had established a cordon of his own body-guard around the building ; in front of the latter, four

sentries were stationed, who were relieved every two hours and were continually watched. Under these conditions the fakir remained in his grave for six weeks. An Englishman, who was present during the whole event as an eyewitness, reported as follows concerning the disinterment, which took place at the end of six weeks: When the building was opened in the presence of Runjeet Singh, the seal and all the walls were found uninjured. In the dark room of the building, which was examined with a light, the sack containing the fakir lay in a locked box, which was provided with a seal likewise uninjured. The sack, which presented a mildewed appearance, was opened, and the crouching form of the fakir was taken out. The body was perfectly stiff. A physician who was present found that nowhere on the body was a trace of a pulse-beat evident. In the meantime the servant of the fakir poured warm water over the head, laid a hot cake upon the top of the head, removed the wax with which the ears and nostrils were stopped, with a knife forcibly opened the teeth, which were tightly pressed together, drew forward the tongue, which was bent backward and which repeatedly sprang back again into its position, and rubbed the closed eyelids with butter. Soon the fakir began to open his eyes, the body began to twitch convulsively, the nostrils were dilated, the skin, heretofore stiff and wrinkled, assumed gradually its normal fullness, and a few minutes later the fakir opened his lips and in a feeble voice asked Runjeet Singh, "Do you believe me now?"

Many other cases have been recorded by witnesses of established veracity, and rarely cases

have been described in Europe. Dr. Cheyne, a well-known physician of Dublin, gives an account of the case of Colonel Townsend. It is so extraordinary that it is worth quoting :

He could die or expire when he pleased, and yet, by an effort or somehow, he could come to life again. He insisted so much upon us seeing the trial made that we were at last forced to comply. We all three felt his pulse first : it was distinct, though small and thready, and his heart had its usual beating. He composed himself on his back, and lay in a still posture for some time ; while I held his right hand, Dr. Baynard laid his hand on his heart, and Mr. Skrine held a clear looking-glass to his mouth. I found his pulse sink gradually, till at last I could not feel any by the most exact and nice touch. Dr. Baynard could not feel the least motion in the heart, nor Mr. Skrine perceive the least soil on the bright mirror he held to his mouth. Then, each of us, by turns, examined his arm, heart, and breath ; but could not, by the nicest scrutiny, discover the least symptom of life in him. We reasoned a long time about this odd appearance as well as we could, and, finding that he still continued in that condition, we began to conclude that he had, indeed, carried the experiment too far ; and at last we were satisfied that he was actually dead, and were just ready to leave him. This continued about half an hour. By nine in the morning, in autumn, as we were going away, we observed some motion about the body, and upon examination found his pulse and the motion of his heart gradually returning : he began to breathe heavily and speak softly. We were all astonished to the last degree at

this unexpected change, and after some further conversation with him, and among ourselves, went away fully satisfied as to all the particulars of this fact, but confounded and puzzled, and not able to form any rational scheme that might account for it.

Readers of the *Master of Ballantrae* will recollect that in his last desperate effort to escape his enemies the "Master", under the guidance of his East Indian friend, went into one of these states of suspended animation. The last page or two is occupied with a vivid account of the efforts of the Indian to exhume the body of his English friend.

"I tell you I bury him alive," said Secundra. "I teach him swallow his tongue. Now dig him up pretty good hurry, and he not much worse." The frost was not yet very deep, and presently the Indian threw aside his tool, and began to scoop the dirt by handfuls. Then he disengaged a corner of a buffalo robe; and then I saw hair catch among his fingers: yet a moment more, and the moon shone on something white. A while Secundra crouched upon his knees, scraping with delicate fingers, breathing with puffed lips; and when he moved aside, I beheld the face of the Master wholly disengaged. It was deadly white, the eyes closed, the ears and nostrils plugged, the cheeks fallen, the nose sharp as if in death; but for all he had lain so many days under the sod, corruption had not approached him, and (what strangely affected all of us) his lips and chin were mantled with a swarthy beard.

The Master returned for one brief moment to life, and then sank into that eternal sleep which he had simulated for over a week.

## CHAPTER III

# RHIZOPODA WITH SHELLS

*A number of different species and sub-species of these interesting animals are known, but much has yet to be found out about the life-history of the opaque shelled forms.*

JUST one hundred and fifty years ago Rösel von Rosenhof[1] saw sticking on the side of a glass vessel of water and weed a particle of jelly, the movements of which attracted his attention. "It fastened itself", he writes, "on the side of the glass and since, like animals, it moves, although very slowly, from place to place, and thereby continually alters its form, and as I frequently examined the water with a magnifying-glass, the creature was necessarily discovered and, as soon as I touched it, it contracted itself into a sphere and fell to the bottom." Rösel removed the specimen to a watch-glass, and observed it continually changing its shape. In consequence of this peculiarity, he named the animal the "small *Proteus*" after the monster of fable. This

[1] August Johann Rösel von Rosenhof was the author of four volumes on "Insects", which he published between the years 1746 and 1761. He also published a *Natural History of Frogs* at Nuremburg in the year 1758, and a further four volumes on "Insects" in the years 1764–1768.

monster was an old Greek sea-god, called by Homer the "Old Man of the Sea". He knew all things, past, present, and future, but was reluctant to reveal his knowledge. First of all you had to catch him, but he eluded capture by assuming all sorts of shapes, such as those of a lion, serpent, leopard, bear, tree, and even fire and water. But if you could only hold him long enough he came back to his original shape, and revealed his secrets.

### Amoeba in General

As the name *Proteus* was preoccupied [1] it was changed to *Amoeba*, and *Amoeba proteus* is one of the commonest kinds we find in our fresh-water pools. Cash has estimated that there were some nine or ten distinct species of this genus in the fresh waters of our country, though some of these are regarded as sub-species. They are usually found in the mud at the bottom of ponds, or creeping about on the algae or water-plants. But certain rare forms are found in the sphagnum moss so common in the bogs of Ireland. *A. proteus* throws out finger-shaped pseudopodia, and may have one or more nuclei. *Amoeba guttula* is a common enough species of very small size; its pseudopodia are hardly noticeable. On the other hand, *A. limax* seems to have a definite anterior end towards which it moves, and as the protoplasm flows forward the cuticle of the hinder end

[1] Preoccupied = already chosen for another animal.

becomes thrown into fan-like ridges as if it were elastic. Many other species are found in the sea, but their validity and their life-history are still matters of considerable anxiety to the systematist and the morphologist. Some *Amoebae*, which are now generally grouped under the generic name of *Endamoebae*, live in the alimentary canal of many animals. One, *Endamoeba coli*, is almost universal in man and apparently does little harm, though *E. histolytica* is the cause of a very active tropical form of dysentery and was one of the most troublesome diseases to deal with during the late war. A particularly large form allied to *Amoeba* organisms is *Pelomyxa*, and when we are hunting the bottom of ponds or ditches we may have the luck to come across specimens of this. At times it attains a length of two to eight mm., and is easily visible to the naked eye. It has an innumerable number of minute nuclei, perhaps as many as 10,000, besides which there are scattered particles of nuclear material known as chromidia.

## Thalamophora

All these forms are entirely naked—except for the thinnest transparent cuticle—and absolutely unashamed. They are grouped together in one of the three great classes of Protozoa, the Rhizopoda, and this class is characterized by the absence of a definite covering and the presence of the power of emitting pseudopodia. The class is divided into six groups, of which the *Amoeboidea* are naked

forms devoid of a shell. But a second order, which is called *Thalamophora*, have a very definite shell of a very definite composition. We will now turn our attention for a moment to some of these *Thalamophora* with their different kinds of shells. There is a little form called *Arcella* with a circular shell, which is again found amongst the mud and weeds of our pools and ponds and lakes. The shell is shaped something like a Chinese labourer's hat or a watch-glass with a cover. In the centre of the cover is a circular opening known as the pylome. The bulk of the protoplasm is contained within the shell, but through the shell opening or pylome a few pseudopodia project and aid the little creature to creep about. The shell is the product of the secretion of the organism. It is at first colourless and apparently consists of a horny or chitinous material which is marked all over with minute hexagons. As the animal grows older the shell enlarges by the intercalation of new hexagons between the old ones; it also thickens and becomes brown, which is the characteristic colour of *Arcellas*. The shell is believed to consist of chitin, a chemical substance found frequently in the animal kingdom; and it is thought by some authorities that this substance is allied to uric acid. The most obvious examples of chitin are the hard cases which envelop the bodies of insects, spiders and myriapods, like plate-armour. The shell is at first transparent and through it can be detected two nuclei and a number of gas bubbles which were at one time thought to contain carbon-

dioxide, but are now believed to contain oxygen. To some extent, undoubtedly, they act as floats and help to keep the animal the right side up. There are two primary nuclei and a scattered amount of nuclear material which is known as chromidium.

## British Species

Reproduction in *Arcella* is like reproduction in *Amoeba*, by division. A large part of the protoplasm emerges from the shell and at the same time each of the two nuclei divides into two, and two of the four resultant nuclei pass into the outside mass, which then separates away and forms the body of a new *Arcella*. But there is a second method of reproduction. At times both the nuclei disappear and then the protoplasm of the body balls itself up round the minute chromidia which act as secondary nuclei. Each of these units now constitutes a spore, and one by one they leave the shell and shortly develop stiff pseudopodia. After a time these spores conjugate in pairs, and each pair, now termed a zygote—for it is the result of the fusion of two reproductive bodies—grows up into a young *Arcella*. This is one of the simplest forms of sexual reproduction we know.

According to a Ray Society monograph published by James Cash in 1905 on the Fresh-water Rhizopods the following species of *Arcella* occur in Great Britain :

(1) *Arcella vulgaris*, which is almost hemi-

spherical in side view. This is found in ponds and ditches and is very generally distributed.

(2) *A. discoides*, which has a somewhat flattened

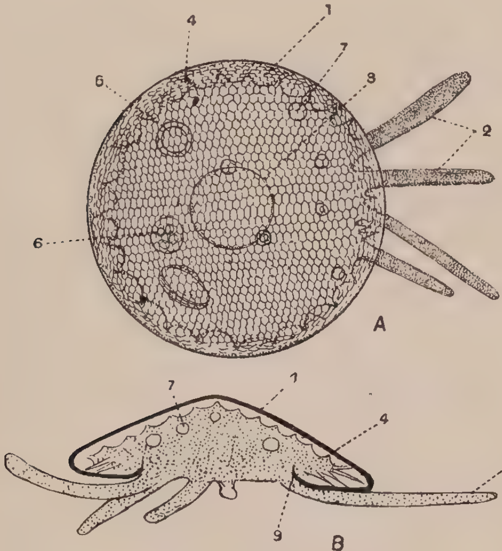



FIG. 5.—*Arcella discoides.* × 500.

(From Leidy.)

A, Seen from above. B, Seen from the side, optical section. 1. Shell. 2. Pseudopodia. 3. Edge of opening into shell. 4. Thread attaching animal to inner surface of shell. 5. Nucleus. 6. Food vacuole. 7. Gas vacuole.

shell. This is less common than *A. vulgaris*, but is frequently found in ponds and marshes.

(3) *A. mitrata.* The shell is balloon-shaped. It has been found amongst moss and Utricularia in Yorkshire and in North Wales.

(4) *A. dentata*, a rather doubtful inhabitant of

our country. It is characterized by spikes protruding from the edge of shell. Specimens very like it have been found by Cash.

(5) *A. artocrea*. The shell is pitted and covered with small dome-like protuberances. Owing to the presence of chlorophyll corpuscles in the protoplasm it is coloured a bright green. This form has been taken in North Wales and in Co. Donegal.

In a later volume by the same author and G. H. Wailes the following are included :

(6) *A. catinus*. This has a number of pores surrounding the central aperture or pylome, usually about a dozen. It is rare in our islands, though not uncommon in America.

(7) *A. arenaria*, with two nuclei and very numerous contractile vacuoles. This form occurs amongst mosses and is widely distributed in Great Britain and Ireland.

(8) *A. polypora*, with from six to twenty small nuclei and many contractile vacuoles. This has been found sporadically living amongst sphagnum and other fresh-water vegetation.

In certain specimens of *Arcella* a small organism has been observed living in the protoplasm. This has been christened *Nucleophaga*, but little or nothing is known about it.

### Gromia

A very interesting case of one of the Rhizopods with a shell is afforded by *Gromia*, a small aquatic organism of singular beauty. The shell is thin

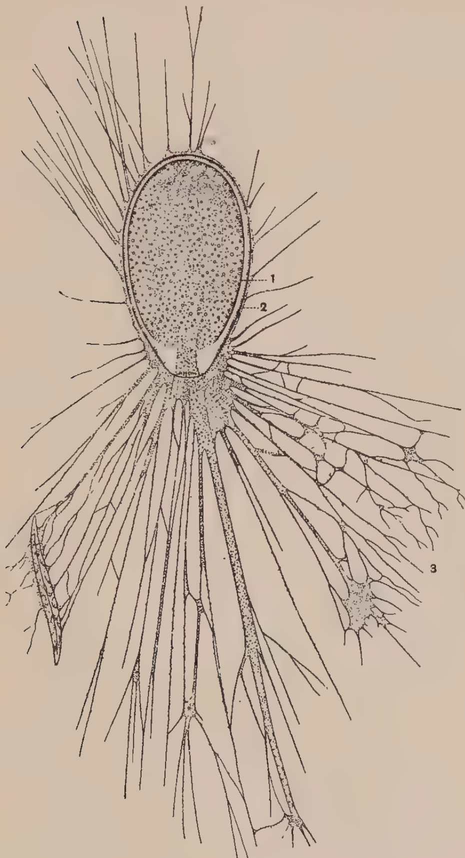



FIG. 6.—*Gromia oviformis.* × 250.
(The Pseudopodia are less than one-third their relative natural length.)
(From M. S. Schultze.)

1. Shell. 2. Protoplasm surrounding shell. 3. Pseudopodia, fusing together in places, and surrounding food particles such as diatoms.

and membranous and shaped something like an

egg with the pylome at one end. It differs from many others inasmuch as the shell is immersed both inside and out in protoplasm, there being a thin protoplasmic layer embracing the whole of the outside of the shell. Again the pseudopodia, which arise most copiously near the pylome, but also emerge from the outer layer of protoplasm, are in all cases thin, delicate threads which at times unite together and form little congrescences of protoplasm in which the food particles such as diatoms are embedded. The thin, almost straight, pseudopodia entangle amongst themselves the living food particles and then proceed to accumulate protoplasm round them which digest the food outside the main part of the body. The digested food is then conveyed along the pseudopodia into the interior. The shell is uniform and shows no markings, but allied forms such as *Quadrula* have reticulated shells. In the last-named genus each shell is made up of a number of quadrilateral areas continuous with one another and secreted by the body. The shell of *Gromia* is flexible and appears to stretch as the animal grows.

An even more interesting case is presented by those members of the *Thalamophora* which build up their shells of extraneous matter. A good example of this is *Difflugia*, shaped like a pointed egg with the blunt end cut off. The blunt end forms a pylome and from it stretch out a number of finger-shaped pseudopodia which may or may not show a series of granules. But the interesting thing about *Difflugia* and its allies is that they

possess a selective power. They pick and choose the substances with which they build up their shell, as a builder picks and chooses bricks as he is building up the shell of a house. No doubt in some cases the selection is governed by the material at hand. The constituents at the bottom of the water are what they have to work on. In some cases these are intermingled, and you may find sand granules, the flinty skeletons of diatoms, the siliceous spicules of sponges, all welded together into a common shell. In other cases the selection is complete. One genus will use nothing but sponge spicules, another will weave a felt of sponge spicules covered on the outside by fine particles of sand. Then again the size of the material selected differs from one animal to another. Some will use fine and some will use coarse material. But the selective power is so considerable that it is used as a specific characteristic. Occasionally shells of their dead neighbours are used, and the whole is welded together by a cement which may be firm or flexible and may consist of chitin, ferric oxide, or calcium carbonate.

## Selective Arrangement

It must be further noted that all these extraneous particles are not casually caught up in a sticky secretion, but are deliberately and of full purpose definitely arranged in position by the animal which has first selected them from their surroundings. As a rule *Difflugia* has only one

nucleus. The chromidia or small particles of nuclear matter in *Difflugia* are united to form a fine network which envelops the nucleus or the nuclei, but in *Arcella* the nuclei are surrounded by a halo of perfectly clear protoplasm. In one species at least of *Difflugia* as time goes on many of the nuclei disappear and the protoplasm undergoes a process of encystment. In the spring the cyst bursts and gives issue to a number of new nucleate secondary cysts, but, as Hamlet says, "the rest is silence". We do not know what becomes of them. Probably they grow up into new *Difflugias*. In *D. urceolata* again in the autumn the protoplasm of one specimen will pass over into the shell of another and fuse with its neighbour, and very frequently the two shells adhere to one another so that we have a full shell containing the fused individuals attached to an empty shell. This double shell arrangement is by no means uncommon. As a rule in this genus the shells are flask-shaped, and some of the largest varieties may reach the length of half a mm.

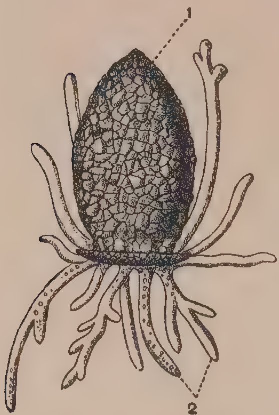



FIG. 7.—*Difflugia urceolata.* × 100. (After Leidy.)

1. Shell composed of particles of sand containing body of the animal. 2. Pseudopodia.

Occasionally the little animal is coloured by minute particles of yellow or blue fat or oil. There is a good deal still to be made out about the life-history of these interesting forms, but the difficulty of investigation is greatly increased by the fact that the shells are in nearly all cases opaque, at any rate in the latest stages of the animal's life.

CHAPTER IV

# PARAMOECIUM OR THE SLIPPER ANIMALCULE

*If you have a microscope and a drop or two of the right kind of dirty water you can enter a new world of interest. In this chapter the author deals delightfully with a familiar animalcule and its cycle of birth, marriage, and death. A wonder tale of microscopic natural history as interesting as the life story of any animal of larger size.*

AMONGST the numerous animals one finds in water which has decaying vegetable matter in it—for instance, in the water in which cut flowers have been left too long standing, or in puddles, especially those which occur near sewage farms—is a little creature known scientifically as *Paramoecium*, and popularly as the Slipper Animalcule. There are several species of *Paramoecium*; amongst the most common are *P. caudatum*, *P. aurelia*, and *P. bursaria*. The last-named is remarkable because it often contains in its protoplasm certain green particles which are regarded by many as minute Algae which help in the nutrition of the host. The body is shaped something like a torpedo but with rounded ends, and one end is

blunter than the other. This end is usually the front end, *i.e.*, the end which moves forward first. *Paramoecium* is just visible to the naked eye, and owing to the large number of refractive granules it contains it looks like a small particle of melted fat or granulated oil. It has a plump, pleasant appearance, like a well-fed puppy. It is always bustling hither and thither through the surrounding water, a veritable Paul Pry. Its shape is permanent, for it is enclosed in a fairly firm cuticle, and, although it can squeeze through openings smaller than its normal self, after all a man can do the same.

## Rhythmic Cilia

If examined under a microscope it will be seen that all over its body are a number of minute, flickering, hair-like processes called cilia (*cilium*, an eyelash), by the lashing of which it rows itself along in the water.

Amongst the most prominent examples of rhythm in nature are cilia. In higher animals they continue their rhythmic movement even after the cells which bear them have been isolated from the rest of the body. The stimulus that induces them to beat now comes from the protoplasm of the cell which bears them, and if this be completely removed the cilia cease to act. The cilia of the Infusoria bustling about in a puddle, or those of the cells lining our breathing tubes, beat in unison and at a definite rate for each individual. The

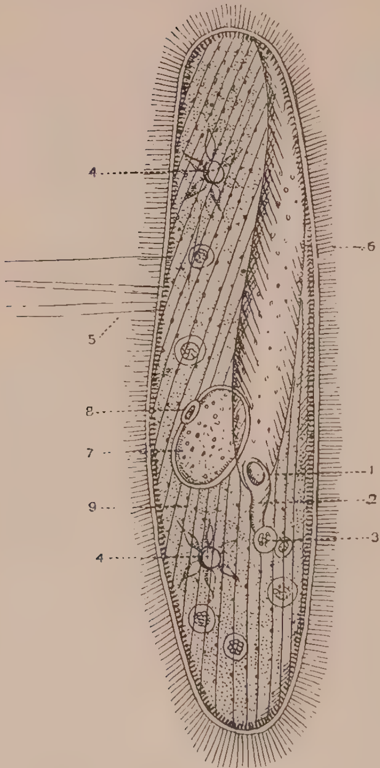



FIG. 8.—*Paramoecium caudatum.* × 250.

(After Butschli.)

1. Mouth at bottom of groove. 2. Mouth. 3. Food vacuole just being formed. 4. Contractile vacuoles. 5. Trichocysts which have exploded; the unexploded ones line the cuticle. 6. Cilia. 7. Mega-nucleus. 8. Micro-nucleus. 9. Contractile fibrils.

beat of the first cilium is followed by the beat of the second, third, and so on. No single cilium ever contracts out of order, and it does not make its appropriate movement till the preceding cilium of the row has moved. It bends just after its neighbour has stopped bending. The first one, as it were, gives the signal to the others. Like the "stroke" in an "eight", it sets the pace. If it ceases to beat, all the others cease to beat; if it starts beating again, the others follow suit. The work they perform is said to be much less than that of muscular movement, but cilia never get fatigued like muscles. They

can keep moving for an indefinite time. It has been determined that a *Paramoecium* 0·25 mm. in length would be able to lift about nine times the weight of its own body by its ciliary action.

Of course the *Paramoecium* really moves very slowly, a few inches each hour, although under the microscope, which magnifies speed as much as size, it seems to move at a great rate. It is said that were this little organism magnified to the size of a pony its velocity would be about equal to that of the pony when galloping. The cilia are arranged in rows, and the *Paramoecium* moves so quickly that it is rather difficult to keep it under the lens. If a little gum-arabic be added, the water in which it is swimming about thickens and the movements slow down ; it can then be examined more conveniently.

## Ectoplasm

Inside the containing membrane or cuticle is a layer of stiffish protoplasm, the ectoplasm, which passes almost imperceptibly in an inner mass of the same substance in a more watery fluid condition, the endoplasm. The minute creature is solid, but on one side of it, which we may call the ventral or underside, is an indentation or pit. This pit leads towards the softer endoplasm. It is lined with special cilia and has besides a flickering membrane with a free edge. By the action of the cilia lining this mouth and of the flapping membrane bacteria and other small

organic particles are drawn into the pit and assemble at the bottom. When a sufficiently large heap has been accumulated the animal gives a kind of gulp and the food particles pass into the soft protoplasm surrounded by a bubble of water. This is called a food vacuole and it circulates in a definite track round the animal, and after a time all that is not digested is passed out at an opening formed *ad hoc*, but always in about the same position. Once it has got rid of the undigested food this opening disappears. The food vacuoles can be clearly seen under the microscope, and so also can two contractile vacuoles. These latter are watery accumulations which increase in size up to a certain point, when they suddenly collapse, and it is believed that their contents are shot out into the outer world. They are thought to be excretory in function and are believed to discharge from the body nitrogenous waste matter, possibly a substance allied to urea.[1]

Somewhere about the middle of the body there will be observed a firmer, darker body, which has close to it a similar body considerably less in size. If the Slipper Animalcule be killed and coloured with some of those stains we used to get from Germany, it will be noticed that these two bodies absorb the stain more densely than the rest of the

[1] As the result of recent research it is probable that the most important function of the contractile vacuole is to get rid of surplus water. Owing to the presence of salts in its protoplasm water is continuously being drawn into it from the external medium. *Paramoecium* would, in fact, soon burst if this extra water were not pumped out by the contractile vacuoles.

animal. They become deeper in colour. These two structures are called respectively the meganucleus and the micro-nucleus, and they take a considerable part in the reproduction of the animal. They also dominate to some extent its nutrition, for if the animal be artificially divided into two parts, one with the nuclei and one without, the latter part is incapable of building up its food into new protoplasm. Its digestive processes slacken and it finally comes to an end, in fact, the part deprived of the nuclei dies in about the same time as the nucleated part would die if it were starved.

## Its Weapons

Lying close under the cuticle and in the dense ectoplasm is a single layer of small rods something like a bundle of cigars. If anything irritates the *Paramoecium* each of these rods shoots out a stinging hair. These are regarded as weapons of offence. They appear to exercise a stunning or numbing effect on any minute animal with which they come into contact.

The specific gravity of the Slipper Animalcule does not vary much from that of water. It seems to be higher than that of the *Hydra*, but this may have been due to some error in the observation. At any rate, the greater part of the protoplasm of the little animal consists of water. The *Paramoecium* obviously has some choice in what it shall feed on. You do not find, for instance, that it swallows minute grains of sand. It is sensitive

to many chemicals and if such be put into the water in which it lives, as soon as it becomes aware of their presence it reverses the action of its cilia and swims for a time backwards. Then it turns over on to its under surface and swims away as hard as it can. This power of swimming backwards is not universal amongst the ciliated organisms allied to the Slipper Animalcule.

*Paramoecium* reproduces by dividing into two. A waist appears about its middle and the waist grows smaller and smaller, like that of a Cretan youth of the Minoan epoch, until it snaps across, and where we had one animalcule we now have two; and if they have a good conceit of themselves each probably thinks it is the parent form. But before this occurs several things happen. Reproduction is usually associated with a process called conjugation, during which two *Paramoecia* approach one another and come into contact along their ventral sides. Their mouths and gullets now disappear and the two finally to some extent fuse. Their protoplasms intermingle and the micro-nucleus in each now divides into two, and one half from each individual passes into the other individual and then fuses with the remaining part of *its* micro-nucleus. Thus it may be said that in a way this micro-nucleus has acted as a male reproductive cell. The animals now separate and re-form a mouth and gullet. The mega-nucleus then breaks up into pieces and is ejected. The new micro-nucleus then breaks up into eight small nuclei, four of which enlarge to form two

new nuclei. When the Slipper Animalcule divides into two, each daughter thus has two nuclei. Then, after a day or two, it divides again and the cycle is now complete, each granddaughter having one mega-nucleus and one micro-nucleus. The whole process suggests that the nucleus had become worn out and must be replaced, or, at any rate, rejuvenated, and to do this it requires nuclear matter from another source.

## Fate of Purity

If you introduce a Slipper Animalcule into a sterile food solution it grows well and multiplies rapidly, and if when the food is exhausted you pick out one of the little creatures and place it in another food solution you may keep the race going for hundreds of generations. Such a race which has sprung from a single individual is regarded as a "pure" race, and, although it may be carried on for years it ultimately degenerates unless some means are taken to restore it. After hundreds of generations the members of a pure race attempt to conjugate, but with no results. They soon begin to degenerate. Imperfect individuals devoid of a mouth appear after fusion, and having no mouth they soon perish for want of food or rather from the want of being able to eat it, like Tantalus, the son of Zeus, who, when ejected from the home of the gods, was unable to take in the nourishment about him. He stood up to his neck in water which sank from him when he bent to

drink it ; further, he had suspended close to his face " rare and refreshing fruits " which the wind blew away when he lifted his mouth to eat them. But in such decaying cultures a little stimulant often starts the strain on a new and vigorous growth. The addition of a little beef tea, a little alcohol rather stronger than " one half of one per cent ", extract from the pancreas or from the brain, a shower of rain, even the mild excitement of a railway trip with the jogging of the train, will stave off for a time the decay of a colony. But these palliatives must continually be applied to avert disaster. If, however, members of a different culture altogether are introduced, then successful conjugation takes place, the vitality of the race is restored and they carry on until the rhythmic incidence of decay again returns, and unless remedial measures are again taken all ends in " death, damnation, and decay ".

CHAPTER V

# THE VORTICELLA OR BELL ANIMALCULE

*In the spring the Bell Animalcules can be found in almost every pond. They are one of the most beautiful and interesting of pond-life objects, and their method of reproduction can be watched under the lens.*

ANOTHER unicellular animal, and therefore a Protozoon, is frequently found in vegetable infusions such as stagnant water and may be very commonly seen on the roots of duckweed. If you take some hay or dead leaves and soak them in soft water, and leave them to stand for a time, the Bell Animalcules are almost certain to turn up in the infusion. After the hay and the leaves have decayed, a brown scum forms on the surface, and on the underside of this numerous specimens are to be found. These are just visible to the naked eye, and scientifically are called *Vorticellae*. Like the Slipper Animalcule, they occur both in freshwater pools and streams and in the sea. One species of them, the *V. monilata*, is easily recognized, because it has little knobs or warts, rather like the rivets which hold metal plates together, all over its body.

## Fixed Anchorage

*Vorticella* differs fundamentally from the Slipper Animalcule in that it is anchored. It is shaped something like a bluebell flower or a bell with a long stalk or handle, and the lower end of this stalk is anchored either to the roots of the duckweed, or to some other fixed point. The bell, however, is not hollow. It is solid and contains the chief organs of the body. Closing the bell is a flat circular structure, ringed about with cilia, called the disk; and between the disk and the edge of the bell, which has a similar row of cilia, is a groove. At one point of this groove it deepens into a funnel, at the bottom of which lies the mouth. A *Vorticella* may live apart from its fellows, or they may be crowded together. But even then they are quite separate and have no organic communication with their fellows. But there are other unicellular animals whose structure closely resembles theirs, which are branched like fluffy feathers, and these indeed form colonies, all the individuals being in organic connexion with one another. In *Paramoecium* the cilia are scattered in more or less regular rows all over the body, but in *Vorticella* they are confined to the rings already mentioned. But they run down towards the mouth opening, which also supports a triangular flap which is said to take some part in bringing food to the mouth. Acting in unison, the action of these cilia produces a vortex (which is Latin for whirlpool), and by their action food

particles are drawn towards the mouth, fresh oxygenated water is brought into the neighbourhood of the animal, which breathes all over its surface, and the excreta are washed away. The shape of the animal is permanent, and this is due to the fact that it is surrounded on all sides by a firm cuticle which, however, becomes much more firm and more thick in the region of the stalk. Under the cuticle we have a thickish layer of protoplasm called the ectoplasm, and this in turn surrounds a thinner, more watery, mass of protoplasm known as the endoplasm, which constitutes the great bulk of the body.

### Corkscrew Action

If we look carefully through a high-powered lens at the body of the *Vorticella*, we shall be able to distinguish certain fine stripes or striae which converge towards the top of the stalk. Here they get together and form a small definite organ, a muscular strand. This strand is attached to the inside of the cuticle of the stalk at short intervals, and in such a way that when it contracts it throws the stalk into a corkscrew-like spiral and the body is suddenly drawn down, it is jerked out of position and is brought down near to the base of the stalk. Should an enemy approach the *Vorticella* with a view of eating it, it suddenly contracts the muscle in the stalk, swiftly changes its position and thus escapes destruction. The jerking is very quick and sudden. At the same time the

disk is also withdrawn into the centre of the groove, and the edges of the groove fold over it. Thus the body is reduced to the shape of a sphere, protected on all sides by the hardened cuticle. After the danger has passed the muscle relaxes and by the elasticity of the cuticle the stalk straightens itself out again.

Inside the body of the Bell Animalcule are many food vacuoles which traverse a more or less permanent path through the soft protoplasm until the food contents have been digested. The indigestible parts are then ejected at a certain definite spot which closes up immediately after the expulsion of the waste matter, and is not seen again until the next food-vacuole yields up its insoluble contents. A very convenient way of tracing the path of the food is to grind up a little Indian ink in the water in which the *Vorticella* lives. Little particles of sepia which form the Indian ink are caught into the whirlpool, carried to the mouth, and passed round the body quite black and undigested to the spot where they are finally ejected. Besides the food vacuoles the *Vorticella* has a contractile vacuole which gets bigger and bigger until it suddenly collapses. The function of the contractile-vacuole has been discussed in the previous chapter.

## Reproduction

Like the Slipper Animalcule, *Vorticella* has a large nucleus (mega-nucleus) and a small nucleus

(micro-nucleus). The first is an elongated rod curved somewhat in the manner of a horse-shoe. Both take up stains more readily than the surrounding protoplasm (this is especially true of the mega-nucleus) and both exercise a control over the single cell which forms the body and stalk of the animal and plays a large part in reproduction.

*Vorticella* reproduces by longitudinal division. The disk and the ciliated groove contract and a transverse depression appears, which deepens and forms a cleft which ultimately splits the body in two. Both micro- and mega-nucleus become dumb-bell shaped and ultimately divide into two halves. For a time the cleft does not reach the stalk, so that we have two bodies supported by the same stalk. One of these will now form an additional circle of cilia at the end near its attachment. It then becomes detached and swims away.

It may now settle down, lose its hinder circle of cilia, develop a stalk, and grow up to be a complete *Vorticella*. Since one form remains on the stalk and one starts out to explore the world, one may here see the first glimmer of parent and child. But this division will not go on indefinitely. For three or four days *Vorticella* will flourish and multiply in an organic solution, but then unless conjugation takes place, the whole community dwindles and finally disappears. In conjugation we find two forms taking part; first the macro-gametes, which are stalked, typical, normal *Vorticellae*; secondly, the micro-gametes, which, as the term indicates, are smaller; they have a

posterior ring of cilia by means of which they

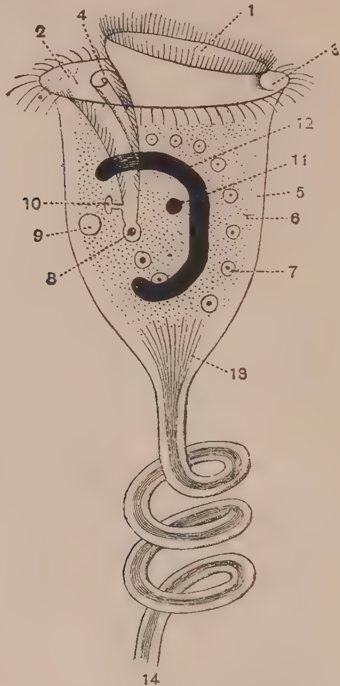



FIG. 9.—Diagram of *Vorticella*.

(The cilia at the side of the mouth have been omitted.)

1. Disk. 2. Mouth. 3. Peristomial groove. 4. Vibratile membrane in mouth. 5. Cortical layer. 6. Endoplasm. 7. Food vacuoles; the last of the food vacuoles is nearing the position of the anus. 8. Pharynx, showing formation of food-vacuoles. 9. Contractile vacuole. 10. Permanent receptacle into which the contractile vacuole opens. 11. Micronucleus. 12. Mega-nucleus. 13. Contractile fibrils running into muscle in stalk. 14. Stalk contracted (the axial fibre should touch the cuticle in places).

swim freely, and, of course, they have no stalk. These forms are brought about, as we have

described above, by the division of the ordinary stalked form. One of the micro-gametes will now approach a stalked form and begin to fuse with it. This it usually does about dawn, and the whole process lasts thirteen or fourteen hours. It pushes its posterior half into that part of the stalked form which is near the commencement of the stalk. Its micro-nucleus now divides into two and it loses its posterior circle of cilia. When fusion is complete, the smaller nuclei of both divide and then divide again, the result being that in the macro-gamete there are four micro-nuclei and in the micro-gamete eight. Seven of the eight now disappear, and three of the four similarly vanish; the remaining two now come into contact, and immediately divide again. Two of these disappear and the two remaining may be regarded one as the male and the other as the female nucleus. They fuse together and form the nucleus of the combined *Vorticella*, *i.e.*, the result of the fusion of the movable micro-gamete and the fixed macro-gamete.

We have in these processes a forerunner of sexual reproduction, and it is important to bear in mind that, whereas in the case of the Slipper Animalcule the two conjugating organisms are of the same size and of the same shape, in *Vorticella* we have one small movable organism which fuses with—one might almost say fertilizes—a fixed form of quite another shape and size. The active micro-gamete, in fact, acts as a male, the passive macro-gamete as a female.

CHAPTER VI

# FLAGELLATES

*Is Euglena an animal or a plant? The question has not yet been decided, for both botanists and zoologists lay claim to the creature.*

We have seen in the last two articles that the Slipper Animalcule and the Bell Animalcule are largely dominated by cilia, whose flickering motion enables the former to move forward, and the latter to bring food to its mouth and fresh water laden with oxygen to its body. But there is another group of animals which we also find in infusions. This group is dominated not by cilia, but by a single large cilium, in this case called a flagellum. One of the commonest of these, named scientifically *Euglena viridis*, is of a deep green colour, for it has on its body the green colouring matter called chlorophyll, which is rare in animals but common enough in plants.

*Euglena* is a very minute organism. At one end of it is the single long flagellum, which is highly contractile and goes through a series of spiral movements, the result of which is that the animal is dragged behind it, just as an aeroplane is dragged along by its propellers. No structure

can be discerned in the flagellum even with the highest power of the microscope, and its movements are something like those of a finger when beckoning. There are other Flagellates which have their flagellum behind, and their bodies are pushed forward by its motion just as a shore-boat is propelled by a boatman waggling an oar at the stern. The fixed end of the flagellum is anchored in a small pit, and its root can be traced through the body to the stiff ectoplasm. The body of the *Euglena* is shaped rather like a blunt torpedo and it goes through a series of very curious movements which are called euglenoid. It is as if a ring of lesser diameter than the body is pressed over the soft yielding protoplasm ; as it passes backward the hinder part is compressed whilst the front swells out. Now it swells up at the hinder end, then in the middle, and then in the front end. These various movements are shown in the illustration on p. 71. The whole body is enclosed in a fairly dense cuticle which is prolonged into the little pit in front, and the cuticle shows obliquely parallel lines which may possibly represent some specialized muscular development of the ectoplasm. But the lines remain when the organism is crushed and the cuticle separated from the body, so that this view is probably not true. About one-third of the length of the body from the interior end is a spherical nucleus.

We have said above that the *Euglena* is green, and when they exist in great numbers, as they

sometimes do, the water in which they live becomes of a bright green tint. But the greenness is not diffused throughout the protoplasm of the body. It is confined to certain spherical or ovoid discs known as chromatophors. Each chromatophor is a separate portion of the protoplasm; through it and it alone the chlorophyll is uniformly diffused. The presence of this green substance enables the animal to do what green plants are doing in sunlight, *i.e.*, to form a starch-like substance known as paramylum. Like starch paramylum has molecules formed by the chemical union of hundreds of sugar molecules of formula $C_6H_{10}O_5$, but it reacts differently and gives no blue colour, as starch does, when exposed to iodine. When there are large numbers of *Euglenae* in a test tube in bright sunlight, bubbles may be seen forming, and if these be collected they will be found to be bubbles of oxygen. Both bubbles and the formation of paramylum cease when the *Euglenae* are kept in the dark. The same is equally true of green plants. From the above statement it seems clear that nutrition of *Euglena* differs from that of ordinary animals. It can build up starch owing to the presence of chlorophyll. It has not been definitely shown that *Euglena* takes any solid food, but as it will live for many weeks in complete darkness, and as it lives in an infusion of organic matter it is said to be saprophytic, that is to say, it can absorb organic substances in solution by the surface of its body like moulds and fungi. *Euglena* is, in

fact, a kind of intermediate stage between an animal, a green plant, and a fungus.

Just behind the base of the flagellum is a vacuole which opens into the pit mentioned above. This is sometimes termed the reservoir, and behind it lie two contractile vacuoles which discharge into it, and it in turn discharges into the pit, sometimes called the gullet. At the front end of the reservoir is a pigment spot called the stigma. This contains a number of minute red granules and, according to some observers, it has in addition a reflecting granule or two of paramylum, the whole structure thus resembling the most rudimentary eye that we are acquainted with. Whether it acts as an eye or not it is impossible to say; though *Euglena* is undoubtedly sensitive to light.[1]

*Euglena* multiplies by dividing into two, and this it does longitudinally and never transversely. The division begins at the front end and gradually passes backwards so that for a time we have two organisms, but still fused together like the Siamese twins. The nucleus divides, becoming at first bell-shaped, and then the constriction thins away until it disappears. There are now two flagella, a new one having been formed on one of the

[1] If left undisturbed in a bowl in a room *Euglenae* swim towards the light and therefore collect on the side towards the window. This phenomenon of attraction to light is known as *phototropism* and is often found in aquatic animals. The advantage of the reaction to *Euglena* is obvious, because it ensures that the organism will always be in the lightest part of the dish, where its chlorophyll will be able to manufacture the greatest quantity of paramylum.

splitting halves of the body. At times the little animal encysts, that is to say, it becomes spherical and surrounds itself with a coating of a gelatinous substance. Under certain conditions these encysted forms may be found in enormous numbers with their gelatinous walls coalescing, and the whole forming a scum underlying the surface film of the water or overlying the stones or other objects at the bottom of the pool. After undergoing a " rest-cure " for some time, the contents of the cyst divide into two, each develops a flagellum, and escaping from the cyst they swim off as young specimens. Occasionally each of the daughter *Euglenae* divide again into two, so that one may find four or even eight young *Euglenae* encapsuled in the cyst. After a time the coating bursts and the young emerge.

## Hard to Classify

The question whether *Euglena* and allied forms are plants or animals is a very debatable one. The presence of chlorophyll, the building up of carbon-dioxide and water into a starch-like substance, and the fact that allied forms can live on organic matter in solution, all rather indicate that they are plants. On the other hand, the absence of cellulose, the fact that they are motile and have a flagellum, points to their being animals. But these criteria will hardly bear rigorous examination. Many undoubted plants, for instance the sea-weeds, the ferns, and the mosses, move

about by means of flagella in certain stages of their life-histories. Further, certain sea-squirts (Ascidians), which undoubtedly are animals, form a sort of cellulose in their bodies. The fact is that we have come to some of the most rudimentary and primitive organisms that we know; and I was going to say that we have come to the most rudimentary plants or animals; but the

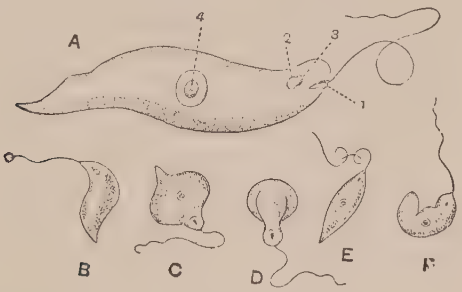



Fig. 10.—*Euglena viridis.*

A × 100, B, C, D, E, F × 200, showing the different shapes assumed by the animal during the euglenoid movement. 1. Pharynx. 2. Contractile vacuole. 3. Pigment spot. 4. Nucleus.

word "organisms" is a useful term, as it denotes anything that is living, without committing oneself as to whether that living being is an animal or a vegetable. We might, in fact, regard *Euglena* as an animal which is trying to become a plant, or as a plant which is trying to become an animal. But the more logical and accurate way is to regard it as an organism which has not yet placed its cards upon the table and determined whether it will go in for a vegetable or animal career.

There are very many different kinds of flagellates. Some, such as *Polytoma uvella*, have two flagella, both of which are actively employed in swimming. This form is colourless and has no chlorophyll to give it a green tinge. Others exhibit a very considerable variety of complicated and more highly developed organs than those we have considered above in the body of *Euglena*. Some of them form a spherical perforated skeleton of flint with a single flagellum waving out through one of the perforations. Others have a skeleton of cellulose, possess chlorophyll, and live entirely as plants. Some have two grooves, crossing each other at right angles, along which the flagella lie. The longitudinal groove shields a minute flagellum and in each transverse groove there is a short and thick flagellum sometimes termed the tentacle. The largest of these, *Noctiluca*, is visible to the naked eye. Sometimes the sea is so full of them that it looks like soup. They are phosphorescent, and as Pepys records, he noticed "the strange nature of the sea water in a dark night, that it seems like a fire upon every stroke of the oar". Another group has a protoplasmic funnel or collar standing up at one end, from the centre of which a flagellum protrudes. The collar is sticky and particles of food are brought within it by the movements of the flagellum and then pass into the body. But the most striking of all the flagellates are certain forms which live in the blood or other fluids of the vertebrates. One of these, the *Trypanosoma*, has its flagellum bent backwards,

and the base of it is connected with the body by an undulating membrane. One form of these parasites causes the deadly sleeping-sickness of Africa. It is conveyed from man to man by a special fly which sucks the blood of an infected person and passes it on to a healthy human being. Still another form causes the deadly horse-sickness, the Nagana, of South Africa. This also is conveyed by a fly, and it is very dangerous to pass through "fly-belts" unless your horses have been salted or made immune.

## CHAPTER VII

# THE VOLVOCINAE

*Volvocinae mark the point where sex and sexual cells begin to make their appearance. Volvox is a fairly common object to the microscopist, but besides being one of the most beautiful subjects for pond-life exhibitions it affords a valuable object for study.*

THERE is a curious family of aquatic organisms known as the *Volvocinae* which are especially interesting because we can trace in various members of the group the origin of sex and sexual cells, and the origin of multicellular organisms from unicellular. Botanists claim these organisms as plants, and there is this to be said from their point of view, that all of them contain chlorophyll and their nutrition is *holophytic*, which means that like plants they are able to build up carbon dioxide into foodstuffs with the aid of sunlight.

### Animal or Vegetable

Zoologists also claim them as animals, for chlorophyll occurs in some animals, though not many; further, they form an extremely interesting

series whose possible ancestry seems animal in its nature. The members of this group all occur in stagnant fresh water.

The simplest method of reproduction is to divide in two as *Amoeba* does, and when the nucleus of the Amoeba is divided in two we have a bicellular organism which soon splits into two unicellular organisms. In the Slipper Animalcule (*Paramoecium*) we have seen that two exactly similar protozoa will fuse together, exchange some of their protoplasm, separate again, and shortly after will reproduce by fission. But these two conjugative organisms are exactly alike. You cannot call one a male and one a female. But in the *Volvocinae* we find indications of sex. The simplest of these organisms now under consideration is known as *Pandorina*. It consists of sixteen cells surrounded by what is known as the colonial cyst or envelope (Fig. 11, *A*). Each cell bulges out on the surface so that the organism looks something like a mulberry enclosed in a transparent case. From the bulging side of the cell two flagella stick out which pierce the colonial wall. Each cell is shaped something like a cone, the apex being near the centre of the little colony. Each cell has a nucleus, a contractile vacuole, a small pigment spot or eye, and is surrounded by a membrane. It also contains a large green corpuscle in which the chlorophyll is confined. Instead of the cells living separately they live together, and there must be some sort of co-ordination between the separate cells, as the flagella beat in unison. If they did

not, orderly progress through the stagnant water would be impossible.

## Cell Division

*Pandorina* reproduces in two different ways. Each of the cells divides into two, then into four, and then into eight, and then into sixteen similar cells. Each of the sixteen original mother cells now contains sixteen similar cells still enveloped in the colonial membrane (Fig. 11, B). This latter, however, softens and finally dissolves, and the new colonies now part company and each of the new sixteen cells develops a new envelope, and the whole develops a new colonial envelope.

This method of reproduction may go on for several generations, but sooner or later forms appear which must conjugate before they reproduce. In this stage the sixteen individuals of the colony divide into only eight cells. The mother colony sinks to the bottom, loses its flagella, and its colonial cyst as well as the original cell-cyst or envelope dissolves. This takes a little time, but ultimately the new colonies formed of eight cells are set free. Each cell develops two flagella and an envelope, and it escapes from the others and swims freely away seeking for a mate.

## Formation of Zygote

When it meets one both unite by their pointed ends and fuse together completely, forming what is called a zygote (a fertilized egg or ovum). For

a time each retains its flagella, so that the zygote

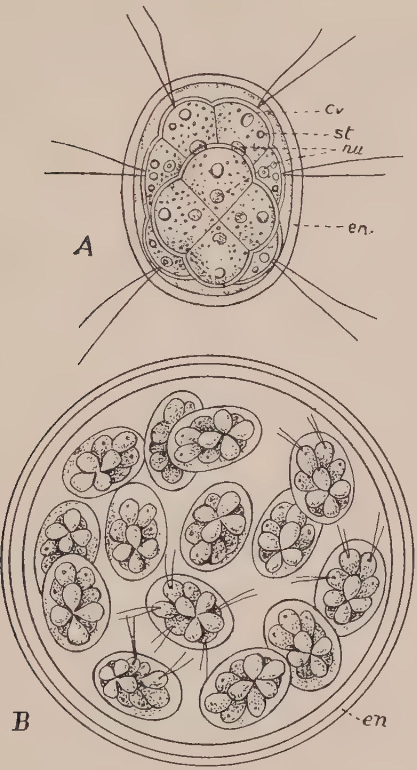



FIG. 11.—*Pandorina morum.*

A, A colony of sixteen flagellated cells, enclosed in a common colonial envelope. B, A colony in which the cells have given rise by repeated binary division to daughter colonies, still enclosed in the common colonial envelope. (*cv*) Contractile vacuole. (*st*) Stigma. (*nu*) Nucleus. (*en*) Colonial envelope. (After Stein.)

has two pairs. Presently it loses these and the

zygote, still a single cell as the result of the fusion of two cells, forms a thick reddish wall round itself and enters upon a rest-cure. From this resting stage it will not emerge unless its surroundings have dried up and, of course, this only takes place when the pool of stagnant water in which it is living evaporates, generally during the hot summer months. When it rains the zygote shows signs of life again. Its envelope becomes thin and the zygote escapes as a naked cell which presently develops a new envelope and two flagella. It then divides into sixteen wedge-shaped cells with bulging bases and forms the colony first described above.

In *Pandorina* the two fusing cells (gametes, as they are called) are of the same size and appearance, there is here no trace of sex. But in some cases there are larger and smaller colonies, and the former produce large gametes and the smaller small gametes. If then the small gametes should conjugate or fuse with the large ones we have the first glimmerings of sex. The larger cell will be the macro-gamete, the equivalent in the higher animals of the ovum. The small cell will be the micro-gamete, the equivalent of the spermatozoon or male cell.

### Bi-sexual Eudorina

Let us now turn our attention to a somewhat smaller organism, *Eudorina*, and we shall find in general structure that the normal creature resembles *Pandorina*; but there are some differences.

It consists of thirty-two cells; but this is not a real difference between it and *Pandorina*, because *Pandorina* sometimes presents specimens which have thirty-two cells. These thirty-two cells of *Eudorina* are enveloped each in a cyst and the whole lot of them are enclosed in a colonial cyst,

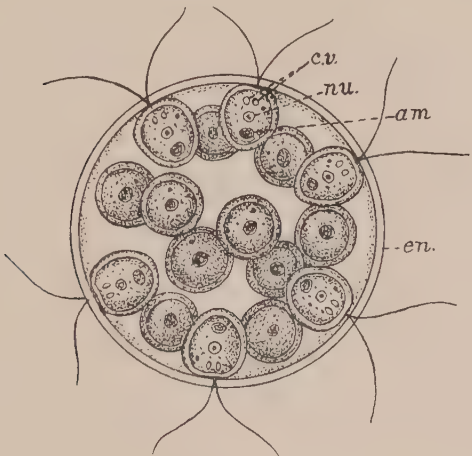



FIG. 12.—*Eudorina elegans.*

The colony consists of thirty-two flagellate cells, situated at some distance from one another, and enclosed in a common colonial envelope. (*cv*) Contractile vacuoles. (*nu*) Nucleus. (*am*) Amylum bodies. (*en*) Colonial envelope. (After Stein.)

and through this cyst each cell puts out two pairs of flagella (Fig. 12). The cells, however, are not necessarily in contact with one another. They are not cone-shaped, but spherical, and their inner ends do not reach the centre of the sphere. The whole organism is small, seldom measuring more

than 0·1 or 0·15 mm. Each cell has in it a contractile vacuole, a nucleus, and a small pigment spot. Each of these cells now multiplies by dividing into thirty-two daughter cells just as happened in *Pandorina*. The colonial cyst then undergoes dissolution, and each little colony escapes to grow up to the size of the original organism. After doing this for several generations a form appears which has marked sexuality. Some of the colonies develop larger and more oval cells, the ova. In other colonies each cell will form a flat plate composed of sixteen or thirty-two cells which are coloured yellow. These are surrounded by a colonial cell wall and, after a time, each of them elongates, becomes torpedo-shaped and develops a pair of flagella which all point the same way. These are now definite male cells or micro-gametes, and as soon as the plate has escaped from the parent envelope the whole plate, very much like a bundle of cigars, swims away to look for the macro-gametes. These they find at rest, and as soon as they get near them the plate breaks up and the micro-gametes separate from one another and work their way through the colonial cyst of the now female colony and ultimately conjugate with the cells, two cells fusing together to form the zygote.

Here we have an example of cells, primarily alike before they divide up, producing male and female cells. But it will be noticed that all the cells can produce these sexual cells. In higher animals and plants this is not the case. A certain

part of the body is set aside for their production, but the great mass of the body is occupied with other organs for feeding, breathing, moving, and so on. The part of the body minus the sexual cells is often referred to as the *soma*, and we get a glimmering of a *soma* in the little creature known as *Volvox*.

## Volvox Globator

*Volvox* is a whole sphere whose walls consist of a single layer of cells. One finds it commonly in ponds and ditches, revolving in a stately way through the still water, just as our globe revolves through space. Each of its cells is somewhat hexagonal in shape, as things are apt to be when there is mutual pressure (Fig. 13). The protoplasm of each cell does not fill up its envelope. *Volvox* is about double the size of *Eudorina*, measuring from 0·2 to 0·7 mm. From each of its cells—and there may be as many as 12,000—protrudes a pair of cilia, and each cell again has a nucleus, a contractile vacuole, and a pigment spot. The protoplasm of each cell is further connected with the protoplasm of the others by fine strands which pierce their envelope. There is, therefore, a certain physical continuity which no doubt aids in the co-ordinated lashings of the flagella. Just as in *Pandorina* if the flagella were unco-ordinated the smooth and even progress of the creature through the water would be impossible.

## Specialized Cells

Each of these cells with its hexagonal-shaped cyst can and does multiply by means of division, and in this way the body of the *Volvox* increases

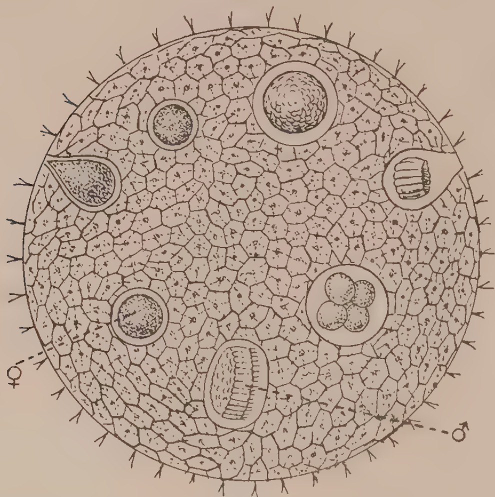



Fig. 13.—*Volvox globator.*

A sexually ripe colony, showing microgametes and macrogametes, in various stages of development. (After Kolliker.)

in size, but unlike the cells of *Pandorina* or of *Eudorina* these cells cannot, except in special cases, reproduce the whole colony. The nutritive cells die after a certain time: they form a mortal body —something to make a corpse of.

*Volvox* reproduces both sexually and asexually. If carefully watched it will be seen that some eight

cells out of the many thousands that make up this revolving globe grow to a larger size than the others, and that these are further conspicuous by the absence of all flagella. These cells are capable of multiplying without any fertilization or conjugation. They gradually give rise to a small new colony which, when it has reached a certain period of growth, drops into the cavity of the mother and is seen lying within it as the ivory spheres of a Chinese puzzle lie one within the other. These cells being produced asexually are often known as *parthenogonidia*. More than one young colony may be in this gelatinous sphere of the mother at one time, but ultimately the spherical layer of cells which forms the mother is ruptured and the young forms swim away to seek their fortune.

*Parthenogonidia* may be produced one generation after another, but sooner or later sexual reproduction will take its place. We then find certain of the ordinary cells become larger and form the potential ovum of the organism. Each cell loses its flagella, becomes dark green and projects towards the centre of the globe. This is the macro-gamete, and unless it is fertilized it comes to nothing. There are some fifty of these cells. The micro-gametes or spermatozoa are also formed from large cells, and at first are indistinguishable from the female cells, but they split up into 128 small cells which lie in a plate something like a bundle of cigars tied up by a thin ribbon. But in time the ribbon bursts, the micro-gametes are set free, and these cigar-shaped little structures make

their way through the central jelly of the globe towards the macro-gametes which are projecting into it. The two cells fuse and form a zygote. This will then round itself off and form a thick shell or cyst of a red colour, and with many projections. Here again, as was the case with *Eudorina*, the *Volvox* does not develop unless it has undergone a period of desiccation or drying up. In this stage the winter is overpassed, and in the warm rains of the spring the zygote comes to active life again and develops into a normal *Volvox*.

Thus we have seen in *Pandorina* that the ordinary cell of the body is capable of conjugating with another cell of the body, but always of the same size. Here all the cells are both nutritive and reproductive. Similarly, in *Eudorina* we find almost the same takes place, but here we get a large cell being fertilized with a small cell, an ovum fused with a spermatozoon.

### Chain of Transmission

But in *Volvox* special cells are set apart for reproduction, and they and they alone can form new colonies. The other cells which take no part in reproduction are vegetative or nutritive cells. We thus meet here for the first time the typical male and female cells, and also for the first time the division of the body cells into cells which are reproductive and cells which are not. In all higher organisms this is the same, and there is a good deal of evidence that in the early stages of segmentation

of the egg—*e.g.*, that of the domestic fly—various cells are set apart which will form the rudiment of the ovary or the testes, whilst the other cells remain nutritive. This reproductive protoplasm is believed to be handed from mother and father to offspring, and in their turn from these offspring to later offspring, so that each individual is, as it were, a bead strung on a strand of this protoplasm. The bead—the body—or *soma* is the individual, the strand is the reproductive plasm or germ plasm.

One of the curiosities of *Volvox* is that one frequently finds a small parasite living in its gelatinous interior. This is a rotifer known as *Proales parasita*. A certain—or rather uncertain—species of sporozoan parasite is also recorded from *Volvox*.

These little creatures, no bigger than a small pin's head, progress forward by the action of their cilia, and, advancing, like a planet they rotate either to the right or to the left, though the latter is more frequently their choice than the former. Watching their majestic and inexorable progress through the water on the microscope slide under a low magnification, one is reminded of W. S. Gilbert's exhortation to the terrestrial globe :

> Roll on, thou ball, roll on !
> Through pathless realms of space
> Roll on !
> What though I'm in a sorry case ?
> What though I cannot meet my bills ?
> What though I suffer toothache's ills ?
> What though I swallow countless pills ?
> Never *you* mind !
> Roll on !

CHAPTER VIII

# THE HYDRA OR FRESHWATER POLYP

*Although Hydra is not a very large genus, specimens of the commoner forms can usually be found by the pond hunter adhering to the thread-like roots of duck-weed. They are one of the most entertaining objects for study under the lower powers of a microscope.*

A VERY common larval form which occurs in all the great groups of animals is known as the *Gastrula*, and the gastrula is formed of two layers of cells. It is, as it were, an india-rubber ball, one half of which has been pushed in until it touches the inside of the other half. This leaves a ball-shaped cavity with a wide mouth, but in the gastrula this mouth soon contracts and is only for a short time equivalent in size to the cross-section of the larva. The *Hydra* is, in effect, a permanent gastrula attached to some submerged object at one end, that opposite the mouth, but the mouth is usually surrounded with a number of thread-like outgrowths, the tentacles.

*Hydra* seems to be a cosmopolitan genus and not a very large one. Schulze has divided it into three genera and some ten species, but recent workers doubt his classification, for any individual

*Hydra* shows as time passes a considerable amount of change in its colour, size, and habits. The two

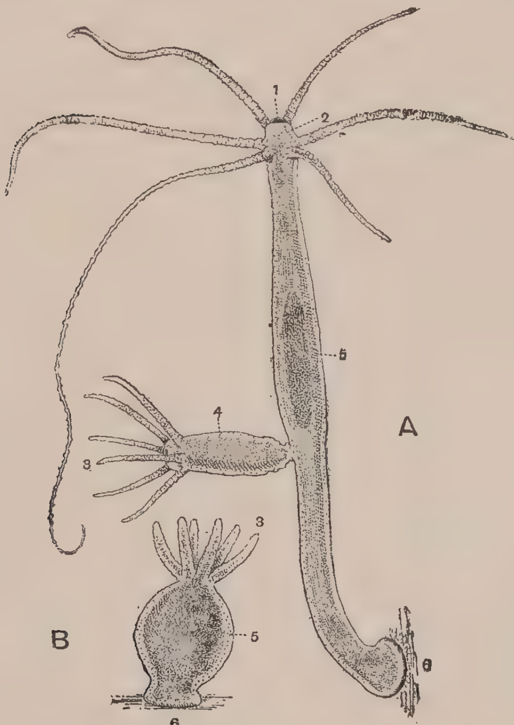



FIG. 14.—*Hydra fusca* × 12.

A, Expanded condition. This specimen is budding off a young Hydra It contains a large food mass in its coelenteron, probably a Daphnia or some other fresh-water crustacean.

B, Retracted condition. 1. Mouth. 2. Oral cone. 3. Tentacles. 4. Bud. 5. Endoderm. 6. Foot. (From Shipley and M'Bride's *Zoology*.)

commonest forms in the streams and pools of our country are *Hydra fusca*, of a yellow or light brown

colour, and *Hydra viridis*, which has a bright green hue due to numerous chlorophyll-containing corpuscles which lie within the cells that form its body. The base of the tentacles are not quite close to the lips of the mouth, but arise a short way behind, thus leaving a small cone-like protuberance known as the hypostome. In number they vary from six to ten.

As a rule the little creature is firmly attached to its substratum, but it can release itself at will, and then it creeps along aided by its tentacles or performs a looping motion like a leech. Both species are a very fair size, from the foot to the tip of the tentacles may be as much as 15 mm., but all parts of the body are very contractile and when irritated the whole collapses into a more or less spherical lump. It is essentially a carnivorous creature and feeds upon certain water-fleas, such as *Daphnia*, and more rarely *Cyclops*, *Cypris*, and occasionally it eats small insect larvae. Larger specimens of water-fleas are frequently caught, but generally make their escape. All these water-fleas have a hard, indigestible, horny cuticle, and when the softer parts have been absorbed by the *Hydra* this cuticle is ejected through the mouth. The prey is caught by means of certain piercing structures called nematocysts, which are especially common on the tentacles. They occur in the outer skin of the body, the so-called ectoderm, and are formed in special cells which have a little projecting process or spike. When the spike is touched the nematocyst explodes, the projecting

spike acting as a trigger. A thread which has been coiled up in its body is shot out and this pierces the skin of an enemy or of an animal destined to form food.

The digestive fluid inside the cavity of the *Hydra* is alkaline, but it seems to have no effect on other specimens of the same genus, for Miss Marshall records having "seen one Hydra completely ingested by another in whose inside he remained for more than twelve hours, and was finally ejected again none the worse".

The cells of the ectoderm split up at their base into two or more processes like an inverted T and these processes are applied to a somewhat elastic membrane which separates the outer layer of cells from the inner layer of cells. These processes are contractile—in fact they are elementary muscle fibres, and it is by their contraction that the animal shrinks in length. These contractile fibrils may be as long as 0·35 mm., and are arranged longitudinally. Each cell has a large nucleus and a very vacuolated protoplasm. Between the bases of the ectoderm cells, which are shaped rather like wine-glasses, in the ample space between their stems are a large number of interstitial cells, and it is these cells which produce the nematocysts.

## Reactions

*Hydra* reacts rather slowly to stimuli. If gently teased with a finely drawn out glass rod a tentacle will contract. If a stronger stimulus be applied

the tentacle will contract over the mouth and then the other tentacles bend upwards till they meet

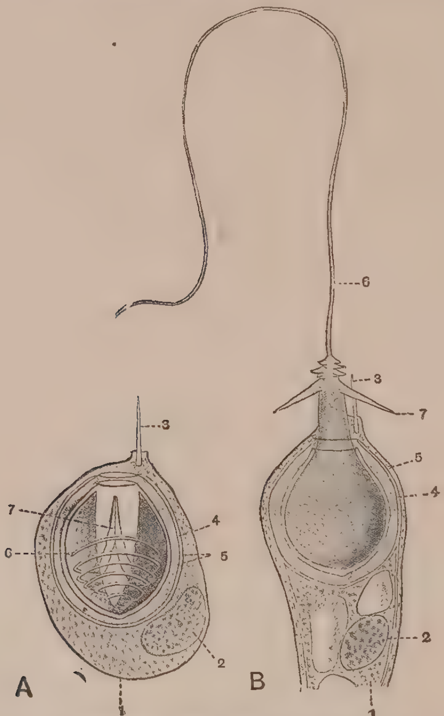



FIG. 15.—Cnidoblast with large Nematocyst from the Bodywall of *Hydra fusca*.
Highly magnified. (From Schneider.)

A, Unexploded. B, Exploded. 1. Cnidoblast. 2. Nucleus of cnidoblast. 3. Cnidocil. 4. Muscular sheath. 5. Wall of nematocyst. 6. Thread. 7. Reflexed processes. (From Shipley and M'Bride's *Zoology*.)

and the " head " turns aside. Tickling the hypostome or the base or foot with a glass rod leads to the contraction of the body. When pieces of

a *Daphnia* are made to touch a tentacle the "capture response" is set up and the piece of food is brought towards the hypostome, the other tentacles bending over it to prevent its escape. Application of very weak acetic acid causes a contraction of the tentacles and the so-called "capture response" is set up. The body is also apt to swerve away from the irritant. The foot and the hypostome seem to be the parts of the animal most susceptible to mechanical stimuli.

The nervous system consists of a series of modified branching cells derived from the interstitial cells at the base of the ectoderm cells. They are of two forms: one, somewhat columnar epithelium-shaped cells whose bases end in only one nervous process; the others, scattered through the base of the ectoderm, are ganglion cells with many processes which are prolonged from each angle of the cells. There may be two or more of these processes, and some of the branches end up by fusing with similar processes from neighbouring nerve cells. Thus some of the branches from neighbouring cells fuse together whilst others are attached to the muscular ends of the ordinary ectodermal cells. These nerve cells are especially concentrated at the foot and round the mouth, and are less common in the centre of the body. The whole system is, of course, diffuse. There is no brain or nerve cord, only a network of nerve cells extending through and between the ectoderm and endoderm cells. Very weak chloroform causes a curious rhythmic contraction of the *Hydra* and

finally the animal becomes anaesthetized. Chloretone, which in human beings is used to prevent sea-sickness, promotes a contrary effect in a *Hydra*. When it is used the *Hydra* shows discomfort and yields up through its mouth masses of endoderm cells.

The nematocysts are divided into three kinds, the first of which are pear-shaped. Their names indicate their functions.

## Weapons

(1) *Penetrants*. These are large pear-shaped nematocysts which are used for piercing the horny shell of the water-fleas. The three large barbs which become conspicuous when a nematocyst has exploded are used as a stiletto which pierces the cuticle of the prey and thus makes the hole through which the filament enters. The barbs are then withdrawn backwards and stick out in a tri-radiate fashion. Apparently some chemical action accompanies the piercing. This is shown by sections made through the cuticle of a captured water-flea. Probably the secretion is poisonous. The thread which is thrust into the body has on it rows of minute pores through which fluid can also escape, as it can through an opening at the end of the thread. These *penetrants* are the lethal weapon of the *Hydra*.

(2) *Volvents*. Volvents are small pear-shaped nematocysts. When they explode their thread winds tightly amongst the hairs or bristles of the

crustacean prey and holds it captive until it has been stung to death by the penetrants. The thread cells of the volvents coil tightly and in an optical section minute hairs can be seen set on the axis. It is also thought that they secrete some sticky secretion.

(3) The third form, the *Glutinants*, are of two sizes. They are not pear-shaped but cylindrical, and one sort is bigger than the other. When the *Hydra* sticks on to its substratum it is by means of the sticky filaments that these glutinants secrete. The secretion seems to harden in water and the attachment is very firm, so firm, indeed, that a *Hydra* in its efforts to pull away the tentacle which is adhering to a glutinant often breaks the tentacle.

## Cell Structure

The size of the nematocyst is frequently used as a means of determining the species, but they vary so much in individual animals that their value for this purpose is almost negligible.

The endoderm cells are closely packed together with very few interstitial cells between their bases. Like the ectoderm cells they are prolonged into muscular fibrils which, however, run around the body and not up and down it. By their contraction the outline of the body is narrowed and elongated. Some of these cells may produce flagella from time to time, or amoeboid processes which project into the cavity of the body. Others

are definitely gland-cells and pour out a secretion which aids digestion. But it is also believed that the individual cells absorb solid particles just as an amoeba does, for inside them are often found food particles, and indigestible nematocysts which

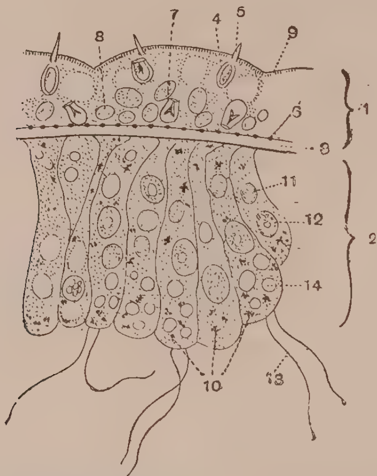



FIG. 16.—Section through the Body-wall of *Hydra fusca*. Highly magnified. (After Schneider.)

1. Ectoderm. 2. Endoderm. 3. Mesogloea or structureless lamella. 4. Nematocyst. 5. Cnidocil. 6. Muscle-fibres of ectoderm cells cut across. 7. Nucleus of ectoderm cell. 8. Interstitial cells. 9. Cuticle. 10. Pigment granule. 11. Food granule. 12. Nucleus of endoderm cell. 13. Flagellum. 14. Water vacuole. (From Shipley and McBride's *Zoology*.)

are ultimately ejected with other indigestible matter.

But the interstitial cells, those little cells tucked away amongst the bases of the ectodermal cells, besides providing the nematocysts have another very important function. They form the ova and

the spermatozoa. The breeding season of the two commonest species in our country varies. *Hydra viridis* produces its eggs and spermatozoa during the summer, whilst *Hydra fusca* delays their formation until October or November. As a rule both ova and spermatozoa are produced by the same animal, a condition of things which is described by the adjective hermaphrodite or monoecious. At the time of the formation of the eggs the interstitial cells multiply abundantly and form a mass which bulges out into the ectoderm. This little swelling can always be distinguished from an initial bud by the fact that the latter contains a layer of the endoderm cells whilst the former does not. In this mass of cells one of them begins to get a little bigger than the others, and finally it eats the others or many of them up and thus greatly increases in size, just as happened in Joseph's dream about the kine. As it develops it forms a hemispherical mass of protoplasm with lobed edges and this lies in contact with the basement membrane. As a rule there is only one ovary at a time with but one ovum, and it is usually found about one-third of the body length from the foot, whilst the testes are generally borne on the upper third of the body. The egg-cell, which is now a very large one, stretches the ectoderm until it is covered by but a thin membrane. After a time this membrane ruptures, and the egg, now naked except for a thin gelatinous coating, is ready for fertilization. Before fertilization the ovum is an amoeboid cell which it is impossible

to distinguish from a free living amoeba except by watching its development.

## Reproduction Methods

The testes arise in very much the same way. There is a great growth of the interstitial cells. After several processes of division the spermatozoa are formed. Each has a conical head containing the nuclear matter and a fairly long vibrative tail, by the lashing of which it moves and makes its way through the water to the ovum. The division of the egg takes place whilst the egg is still associated with the body of its parent. The young *Hydra* finally creeps out of its shell and attaches itself to some extraneous object.

But *Hydra* also multiplies asexually. It can throw out a bud. At first a small knob involving both layers appears and this increases in length till it may almost equal its parent, then it forms a mouth at the free end and throws out a ring of tentacles around it. The bud may even have a secondary bud on it, and thus we get a small colony such as is so common in the higher groups of Coelenterata.

CHAPTER IX

# ROTIFERS

"*Make them like unto a wheel.*"—PSALM lxxxiii. 13.

On the Somersetshire side of the Avon, and not far from Clifton, is a little combe, at the bottom of which lies an old fish-pond.

Its slopes are covered with plantations of beech and fir, so as to shelter the pond on three sides, and yet leave it open to the soft south-western breezes, and to the afternoon sun. At the head of the combe wells up a clear spring, which sends a thread of water trickling through a bed of osiers, into the upper end of the pond. A stout stone wall had been drawn across the combe from side to side, so as to dam up the stream; and there is a gap in one corner, through which the overflow finds its way, in a miniature cascade, down into the lower plantation.

. . . . . .

But if, retaining sense and sight, we could shrink into living atoms and plunge under the water, of what a world of wonders should we then form part! We should find this fairy kingdom peopled with the strangest creatures: creatures that swim with their hair, and have ruby eyes blazing deep in their necks

with telescopic limbs that now are withdrawn wholly within their bodies and now stretched out to many times their own length. Here are some riding at anchor, moored by delicate threads spun out from their toes; and there are others flashing by in glass armour, bristling with sharp spikes or ornamented with bosses and flowing curves; while, fastened to a green stem, is an animal convolvulus that by some invisible power draws a never-ceasing stream of victims into its gaping cup, and tears them to death with hooked jaws deep down within its body.

These lines are taken from the introduction to the classical monograph on the *Rotifera* by Hudson and Gosse, and yet people say men of science cannot write English! They introduce us to the study of a number of small animals which are infinitely more complex than the unicellular protozoa which we have hitherto been considering.

The Rotifera are a somewhat isolated group, and their affinities are obscure. Some of them are just visible to the naked eye, though many of them are but 0·2 or 0·3 of a millimetre in length, and others, especially the males, are much smaller. The very great majority of them are found in fresh water, very few being found in the sea. Some of them are permanently anchored, their body being produced into a stalk which adheres to some substratum. But most of them swim actively about by the action of a loop of cilia at the front end of the body. The action of the cilia produces

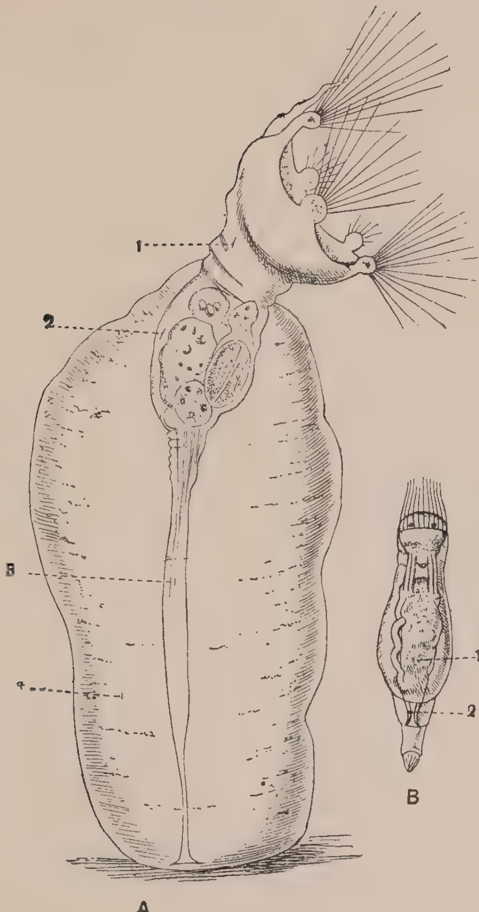



FIG. 17.

A, *Floscularia cornuta*. Female (magnified). (From Hudson.) 1. Head. 2. Trunk. 3. Foot. 4. Gelatinous tube in which the animal lives.
B, *F. campanulata*. Male (magnified). 1. Vesicula seminalis. 2. Penis.

the appearance of wheels going round, and the early observers in the seventeenth century thought they carried wheels : hence the name of the group. There is a distinct alimentary canal which opens in front by a mouth which comes within the loop of cilia. The other end generally opens near the lower part of the body.

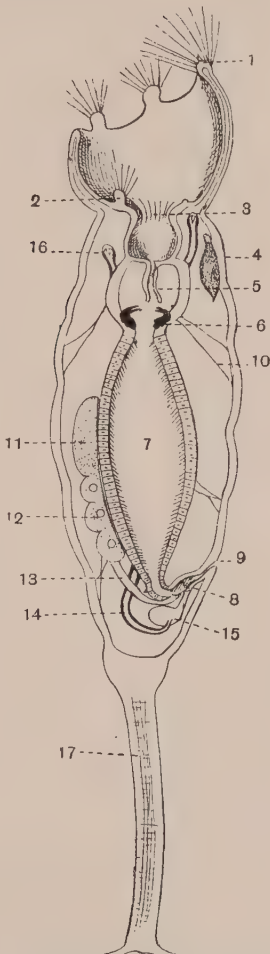
The whole animal is enclosed in a more or less firm, elastic cuticle, and as part of the outside of the body is tucked in to form the mouth the cuticle also goes in with it, and here it is thickened to form two horny jaws which crush against each other and tear to pieces the minute animals and plants, brought towards the mouth by the action of the cilia. These jaws form the "mastax".

Rotifers are singularly beautiful little animals, and it seems a pity that their "glory should be concealed" from all those who have not a microscope at their command. One of the most graceful and beautiful of them is termed *Floscularia cornuta*, which is very widely distributed in our ponds, ditches, and pools. To protect itself it secretes a gelatinous tube into which it can retreat when exposed to attack. At the base of the stalk are two large glands which secrete the sticky substance which serves to anchor the little animal, for *Floscularia* is a fixed form, "sessile" as the zoologists say. Its front end is produced into a funnel-shaped cavity which at equidistant points supports five bunches of bristles, which act as a trap for small animals and plants. At the bottom of the funnel is the mouth. Around the mouth is

a horseshoe-shaped loop of cilia whose action

FIG. 18.
Diagram of *Floscularia.*

1. Circle of tentacles bearing bristles.
2. Outer ring of cilia.
3. Mouth leading to vestibule.
4. Brain.
5. Oesophagus hanging like a funnel into the crop.
6. Mastax with jaws.
7. Stomach.
8. Rectum.
9. Opening of Cloaca.
10. Strands of muscles.
11. Yolk-gland part of ovary.
12. Ovarian part of ovary.
13. Oviduct.
14. Excretory duct opening into
15. urinary bladder.
16. A tag with a tuft of cilia.
17. Longitudinal and circular muscles in foot.




produces a tiny whirlpool, dragging down into the

gaping mouth the numerous minute organisms which form the food of the *Floscularia.*

As sometimes happens in certain groups of animals, the outer layer of cells, known as the ectoderm, have their surfaces undeliminated. They have fused together in a common sheath of protoplasm. Scattered through this layer of protoplasm are a number of nuclei. Within the ectoderm and surrounded by it is a cavity full of watery fluid with no corpuscles, and in this float the more important organs of the little creature. In most animals there is a packing tissue in which the various nerves, muscles, glands, and cells are embedded, much as pottery in a crate is embedded in straw. But in Rotifers this packing or "connective tissue" is at a minimum, and one can generally see with some clearness each individual cell. One can even count them, for they are not very numerous, at the outside many hundreds or a few thousands which, compared with the millions and millions that go to make up the body of larger animals, seems a very small number. The muscles are not banded together, but consist of isolated strands whose chief duty is to withdraw the anterior end into the body when in danger, and to bend the body in various directions. The recovery is effected by the elasticity of the cuticle.

## Their Food

Rotifers feed largely on protozoa and minute plants which are floating about in the water and

are caught up in the whirlpool developed by the cilia. This food is passed down into the mouth and ground up by the jaws mentioned above. These jaws are often very complicated. The whole structure is called the "mastax", which is one of the most characteristic organs of the Rotifera, and its presence helps to differentiate them from other groups of the animal kingdom. In a few the mastax can be pushed out through the mouth, and it is then used to cut away part of the tissue of larger algae upon which these Rotifers browse.

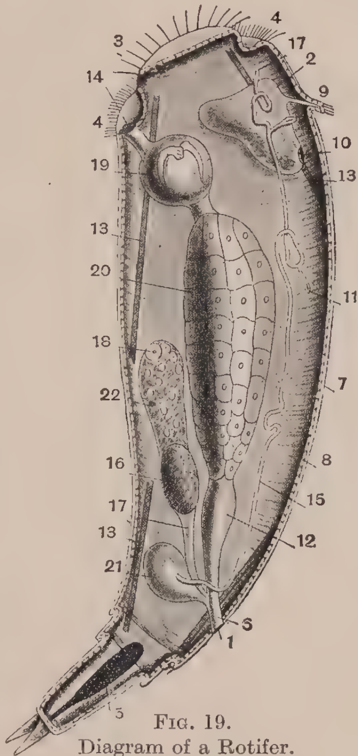



FIG. 19.
Diagram of a Rotifer.

1. Anus. 2. Brain. 3. Inner ring of cilia. 4. Outer ring of cilia. 5. Gland in foot. 6. Cloaca. 7. Cuticle. 8. Ectoderm. 9. Dorsal antenna. 10. Eye. 11. A ciliated "tag" of the excretory system. 12. Intestine. 13. Muscles. 14. Mouth. 15. Excretory tube. 16. Ovum. 17. Oviduct. 18. Ovary. 19. Mastax. 20. Stomach. 21. Bladder. 22. Yolk-gland.

Beyond the mastax the food enters the stomach, which is

lined with cilia whose flickering presses the food onwards. There are two salivary glands and, in many cases, two gastric glands which open into the alimentary canal. The stomach ends in a simple tube or rectum which also receives the products of the genital and excretory systems. The latter consists of two longitudinal ducts which pierce a column of cells. Communicating with these are a number of tags or so-called ciliated cells. The two ducts in *Floscularia* communicate with one another at the front end of the body by means of a transverse loop. At the other end they both open into a capacious bladder which contracts at intervals and expels the waste nitrogenous matter, which it has accumulated from the fluid in the body cavity, into the rectum and so out of the body. The excretory organ is a very active organ and in some species the bladder expels a bulk of fluid equal to the bulk of the whole animal every ten minutes or so. This fluid must be replaced by water which soaks in through the skin, and doubtless brings with it oxygen for respiration, for there are in Rotifers no gills or lungs. The excretory organs carry off the carbon dioxide given up by the tissues.

On one side of the mouth is a small ganglion which is called the brain, and in *Floscularia* it bears two red eyes. In some forms there is another ganglion on the other side of the mouth, and the two are connected by a circular cord. From this central organ nerve-fibrils are given off to all parts of the body.

The reproductive organs are comparatively simple, but they have one complication. The ovary does not, as in a chick, provide the yolk and the female reproductive cell or egg as well. It only gives rise to the latter. The yolk is derived from a different gland known as the yolk-gland. There may be one or two ovaries and one or two yolk-glands. Each is enclosed in a membrane which is continued into an oviduct or a yolk-duct, and these, as we have said above, open into the rectum just behind the opening of the excretory duct. Through this the eggs, now surrounded by yolk and enclosed in shells, leave the body of the mother and pass into the surrounding water.

Rotifers exhibit a very marked sexual dimorphism and, in the case of *Floscularia* the male is, as is usual in the invertebrates, much smaller than the female. All its organs are reduced and its mouth and alimentary canal have disappeared altogether. They simply do not exist. Most of the interior of the male is taken up by the testes, which produce the spermatozoa. These are injected into the cloaca of the female in some Rotifers, and there the egg is fertilized. In other cases they are introduced at any part of the body wall and then the spermatozoa probably fertilize the eggs whilst still in the ovary.

Like many of the smaller fresh-water animals, *Floscularia* lays two kinds of eggs, in fact even three. During the summer there are (i.) large eggs averaging five to eight in number which accumulate between the stalk and the gelatinous cyst.

These give rise to females. There are moreover (ii.) smaller eggs, some eighteen to twenty in number, which turn into males. The production of these seems to be more or less dependent on the temperature. Both these large and small eggs develop without any fertilization, but towards the autumn the third kind of egg (iii.) known as the winter egg, turns up. These eggs are invariably fertilized ova and are thus produced sexually. They are covered with a thick coat or shell which is capable of withstanding the effects of cold and drought. They live through the winter, when the adult Rotifers are apt to die down and disappear. In the following spring, as the weather warms, they give rise to the normal female which soon starts producing parthenogenetically—*i.e.* without fertilization—the larger and the smaller eggs.

The class Rotifera is not a very large one. Between 700 and 800 species alone are recognized and about one-tenth of these inhabit the sea or brackish water. A very few are parasitic and one species, *Synchaeta baltica*, floats on the surface of the water and is phosphorescent. Some of them can survive being dried up for a long time, the body shrinking and sealing itself up in its cuticle. They can thus be sent about, hidden amongst dried roots or leaves or mosses, from all parts of the world, and brought to life again in the laboratory by soaking them in water. Apart, however, from these forms, Rotifers, especially male Rotifers, are short-lived.

CHAPTER X

# WATER FLEAS

*The water flea is one of the commonest of our pond crustaceans, though they are almost all females. The male is relatively rare and seldom found by the pond hunter.*

AMONGST the more primitive of Crustacea is a group of small animals known as the *Cladocera*. These are small animals, but the females often reach five millimetres or more in length. They are very widely distributed throughout the world, and they occur not only in fresh water but in the ocean. Two of the commonest of these little creatures found widely spread through the old and new worlds are called *Simocephalus* and *Daphnia*. The body of these animals is enclosed in a chitinous shell which is fused with the head end, but for the last three-quarters of the length of the animal it is free. It hangs down in two wide flaps just as the valves of a mussel or clam shell do. It envelops the body very much like a lounge-coat, only, of course, a lounge-coat is not fused with the head.

The abdomen is generally folded forward beneath the surface of the body, but can be protruded from between the hinder edges of the shell.

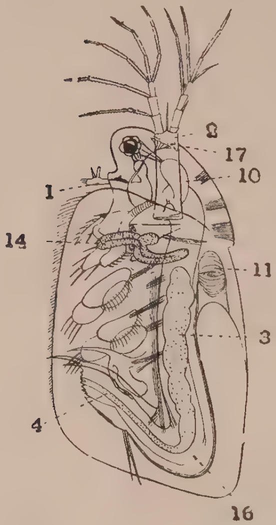



Fig. 20.—Side view of male *Simocephalus sima*. Highly magnified.
1. Antennules. 2. Antennae. 3. Testis. 4. Vas deferens. 10. Hepatic diverticulum. 11. Heart. 14. Shell-gland. 16. Mid-gut. 17. Neck organ.

The head and body bear a number of appendages or limbs. These are as follow :

The first antennae, which are rudimentary and bear a few hairs, which are believed to be olfactory in function. The second pair of appendages are the second antennae, which are large and stout and take a large part in the swimming movements of the animal. These second antennae are very conspicuous. They stretch out in front of the little creature and incline backward.

## Leaf-like Legs

They are very much like the arms of numerous little men in Edward Lear's illustrations of *The Book of Nonsense*, and as these little men wear little jackets there is a somewhat ludicrous resemblance between *Daphnia* and them, though it is

quite impossible that any Cladoceran should ever have seen this work, and extremely improbable that Mr. Edward Lear ever saw a *Daphnia*. Then come a pair of biting mandibles, and then the first pair of accessory mouth parts or maxillae. The second pair of maxillae, which are present in other Crustacea, have disappeared in *Daphnia*. At this point the thorax begins and bears five pairs of flattened, leaf-like legs. These are continually waving to and fro, producing a current which flows through the shell, bringing with it food and oxygen. Behind the fifth pair of legs there is an unsegmented abdomen which is usually bent under the body. The shell is to some extent transparent, and one can generally observe the curved gut or alimentary canal, which has a pair of digestive glands opening a little way behind the mouth, for this tube is generally packed with coloured food. It opens on the exterior of the upper side of the tail. Then one can also make out the shell-glands, which act in these small animals much as a kidney does. These lie between the walls of the valves of the shell and open in the region of the second maxillae, which are, however, wanting. The nervous system consists of a brain with a large nerve to the eye and of a series of segmented ganglia supplying the appendages of their neighbouring parts.

## Single Eye

These can all be faintly made out. The sense organs consist of a very large eye which is the result of the fusion of the middle line of the two lateral eyes. This eye is moved hither and thither by three muscles, and when they contract, the eye, like that of the poet, appears "in a fine frenzy rolling". Besides this it has a perpetual quivering motion, as if it were always winking, or, at any rate, twinkling. In the embryo the two eyes are distinct; later in life they fuse. Besides this, there is a small median pigmented spot which represents what is left of the crustacean central eye, just as our pineal gland represents what was an eye in the lower vertebrata. The faculty of smelling is attributed to many of the hairs which are found on the antennae.

In the female we can also distinguish the ovary, and in the rare specimens of males the testes. The beating of the little creature's heart can be counted. This last-named organ has a pair of openings or ostia. When the heart expands blood is sucked into it through these openings from the surrounding tissue spaces, and when it collapses these ostia close and the blood is forced forward in a stream which, although there are no definite blood vessels, always follows the same course. It streams through the thin leaf-like legs which flap to and fro. It also streams between the inner and outer walls of each flap of the shell.

*Daphnia* has a certain historical interest, for it

was in this little creature that Metchnikoff observed some of the earliest examples of phagocytosis. This great Russian zoologist observed that certain sharp spores of a fungus known as *Monospora*, when swallowed by the *Daphnia*, pierced the walls of the intestines, and, getting into the " body cavity ", were eaten up and put out of action by the amoeboid-like corpuscles in the blood of the *Daphnia*.

## Casts

The ovary lies alongside the intestine and opens at the beginning of the thorax into the space between the body and the upper part of the shell. Here is a roomy cavity and here the eggs develop, generally several at a time. They are prevented from tumbling out behind by the presence of a couple of spur-like processes projecting from the upper side of the abdomen.

From time to time the animal undergoes " ecdysis ", that is, it casts its cuticle as do all the Crustacea, and it does this with extreme rapidity, taking less than a minute for the whole process. The shell is chitinous for the most part, but strengthened by a certain amount of calcareous deposit. It does not seem quite clear how many ecdyses take place, but when one does occur, the shell cracks and the head part separates from the two shell flaps. The head is then almost free and through the split which has been formed first the head and then the shell flaps and then the hinder

parts of the body push their way out. In the meantime the shell has also split along its middle dorsal line, and this helps in the escape of the body from the cast-off cuticle. During this process all movement is slowed down, the lashing of the feet and the beating of the heart almost cease. The freed Water Flea is extremely transparent and for the moment very soft and weak. It remains quite quiet, the legs languidly moving, but as the minutes pass it darkens and becomes stronger. For a time it fasts, but somewhere between the fifth and ninth hour it begins to feed and to " sit up and to take notice ". In the course of a day the animal becomes normal.

## Activities

The Cladocera swim actively through the water, sometimes head forward, sometimes breast forward, sometimes upside down. But they are fond of resting and *Simocephalus* will hang on with certain curved hairs of its antennae to any slightly roughened surface and will remain in the same place for a considerable time. Whilst resting, the legs will beat at an amazing rate, not less than 300 strokes per minute, though these may in cases slow down. The heart beats almost at the same rate, but there is no exact correlation between the movements of the limbs and of the heart. As a rule the heart beats rather more slowly.

One of the most remarkable features of the Cladocera is their method of reproduction. The

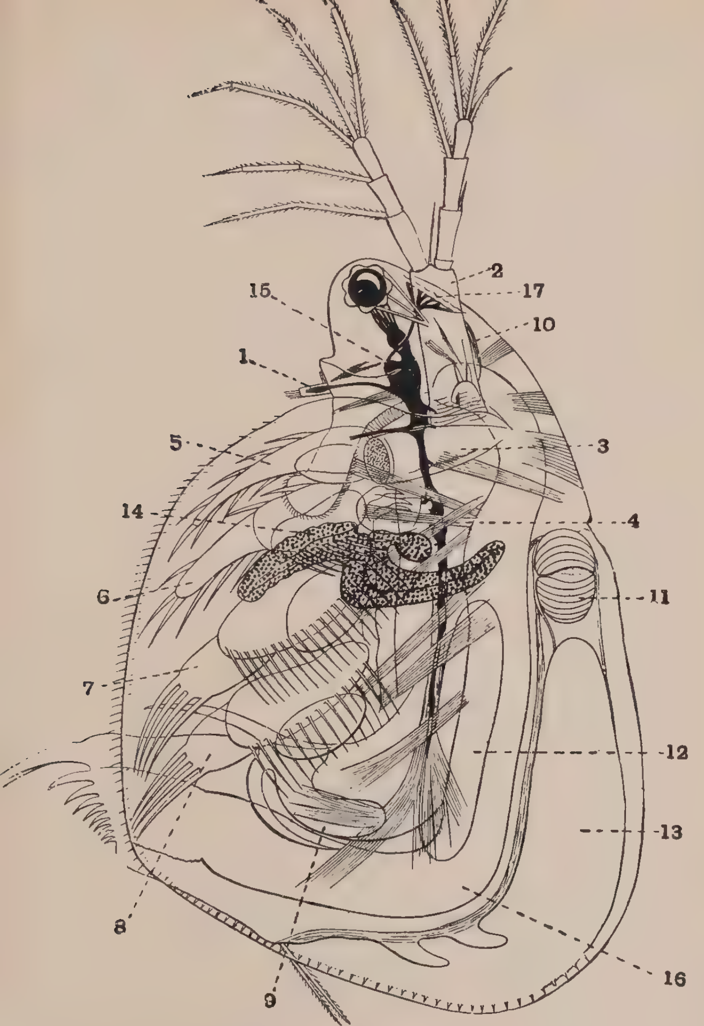



FIG. 21.—Side view of female *Simocephalus sima*.

Magnified to the same extent as Fig. 20. (From Cunnington.)

1. Antennules. 2. Antennae. 3. Mandibles. 4. Maxillae. 5. First pair of legs. 6. Second pair of legs. 7. Third pair of legs. 8. Fourth pair of legs. 9. Fifth pair of legs. 10. Hepatic diverticulum. 11. Heart. 12. Ovary. 13. Brood-pouch. 14. Shell-gland. 15. Brain. 16. Mid-gut. 17. Neck organ.

eggs, when laid, pass into the space under the shell above the body and here they undergo their development. They pass through a larval stage known as the *nauplius*, which is just as characteristic of the lower Crustacea as the caterpillar is of moths and butterflies; but in *Daphnia* this stage exists only whilst the embryo is in the egg-case. The little creatures actually hatch out as miniatures of their parents. During most of the year all the specimens of this very widely distributed group are females, which reproduce their kind parthenogenetically or without fertilization. This condition of things may last on, should the winter be mild, till Christmas time, but with the onset of cold weather some of the eggs hatch out as males. The male is a small, puny, insignificant copy of the female, as is so often the case with males of all classes of animals until we reach the Vertebrata. It, however, fertilizes the eggs of the female and these eggs, passing into the brood-case, develop up to a late stage of development but no further. Soon after their arrival in the brood-case the shell is thrown off, but part of it remains as a coating to the eggs and this is called the ephippium. Surrounded by this protective casing the eggs lie dormant through the unfavourable times; with the return of warmth and brighter conditions the eggs continue their development and hatch out as parthenogenetic females, which continue to reproduce their species asexually. In some species there is a second period of sexual reproduction in the summer, the cause of which is not very clear.

As a rule there are only two winter eggs within each ephippium. They float about near the surface, or, if the pond dries up, lie buried in the mud, and in this way they can be sent all over the world and hatched out by those who wish to study foreign species. The number of summer eggs may, in *Daphnia*, amount to some thirty, while others, *e.g. Simocephalus*, has rarely half that number, and in the ephippium of the last-mentioned genus there is only one egg instead of two.

## Response to Changes

Water Fleas are attracted to the light, that is to say, like *Euglena*, they are positively phototropic. They will pass from a dark place to a lighter place. Possibly this may have something to do with their feeding, for the same stream which brings oxygen to the leaf-like legs brings also some unicellular plants, diatoms, etc., which in some rather mysterious way collect along the ventral surface of the animal between the bases of the appendages and are swept forward towards the mouth, where they are engulfed between the mandibles. Animal food seems less common than vegetable. Recent observation has shown that specific gravity plays some part in the vertical distribution of such creatures as *Daphnia*. There are so many factors at work, the temperature of water, its density, light, and many other agents play a part in the rise and fall of the Water Fleas in the ponds in which they live. The specific gravity of *Daphnia*

*pulex* varies with the amount of food in the intestine and the number of young in the brood-pouch. The release of the latter causes an instantaneous decrease of specific gravity of the mother, who consequently floats to the surface after hatching her brood. There is also a diurnal variation in the specific gravity of animals of the same size. It varies at different periods of the day and night, being at its maximum before sunrise and approaching its minimum by noon.

## CHAPTER XI

# CYCLOPS

*In both salt and fresh waters the Copepoda are one of the most important sources of food for fish. They are common in many ponds and ditches and are fascinating objects to watch under the microscope.*

THERE is a large group of small Crustacea known as Copepoda, a word derived from the Greek, which means the "oars as feet". Amongst them is a small creature known as *Cyclops*, which, like *Daphnia*, is often vaguely referred to as a "water-flea". It is a small animal hardly a millimetre in length. Its body is sometimes compared in shape with one-half of a split, rather longish, pear. The *Copepoda* occur both in fresh water and the sea. *Cyclops*, however, is exclusively fresh water, and does not even penetrate into brackish streams. They are common enough and very abundant in the weeds of lakes or pools or slow-flowing streams. The late Geoffrey Smith records taking large numbers of *C. fuscus* and *C. strenuus* in the weedy inshore waters of Grasmere, but the genus seems to be practically ubiquitous in fresh water, and some species are taken on the surface waters far from the shore.

Others, again, dwell in subterranean springs and are occasionally brought to the surface by artesian wells. In such places they have, like many other animals that live in the dark, lost their eyes and lost their colour. If one examines a *Cyclops* under a low power of the microscope one will see that it moves about by the sharp jerky motions of its first antennae, and more steadily and more uniformly by the rowing of its feet.

## The Head

There is no valve-like shell such as we find in *Daphnia*. The body consists of a large rounded head which may terminate in a process or spine, and in a thorax consisting of, in the male, five rings or segments, and in the female four, two having fused into one in this sex. The abdomen, which represents the narrow end of our split pear, ends in two symmetrical processes together called the caudal fork, and each process bears a number of feathered hairs. The appendages of the head are as follows: (i.) The first antennae. These are large with eight to seventeen segments, and in the male they serve as a clasping organ to hold the female when the eggs are being fertilized. These antennae in both sexes take some part in swimming. (ii.) The second antenna is small and insignificant. The relative importance of the two pairs is just the reverse of that in *Daphnia*. Then on each side of the mouth is (iii.) a large and strong mandible, somewhat squarish in shape,

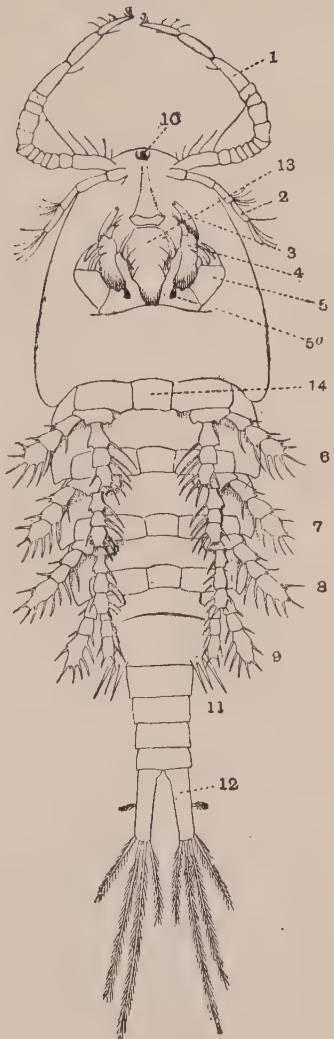



FIG. 22.—Ventral view of male *Cyclops*.

1. Antennule.
2. Antenna.
3. Mandible.
4. First maxilla.
5. The two halves of the second maxillae sometimes called inner and outer maxillipedes.

6-9. First-fourth thoracic limbs.

10. Eye.
11. Bristles near male generative opening.
12. Caudal fork.
13. Mouth.
14. Copula or plate connecting the right and left limb of each pair.

and bearing numerous little teeth. This takes a large part in crushing the food of the *Cyclops*. It bears a small sensory organ or palp, but in the *Cyclopidae* this is extraordinarily small. Following on the mandible come a pair of (iv.) first and (v.) second maxillae which serve the food to the mandibles. The second of these is split into two conspicuous halves. These five appendages constitute the normal appendages of the head on a normal crustacean.

## Conjoint Legs

The head is not separated from the thorax by any neck or constriction. On the first four segments of the thorax there are paired appendages which are shaped something like an inverted Y. These limbs are flattened and consist of short broad joints bearing many spines. The right and left legs of any pair are further joined together by a flattened plate so that when one moves the other has to move. It is these limbs that have given rise to the German name of oar-footed crabs, which is that nation's common name for the whole of the Copepoda. When the whole eight move simultaneously the little *Cyclops* darts through the water. On the other hand the swimming movements of the first antennae produce a slow and gliding motion. All this time the maxillae are producing a sweeping current in the neighbourhood of the mouth bearing towards it the suspended food.

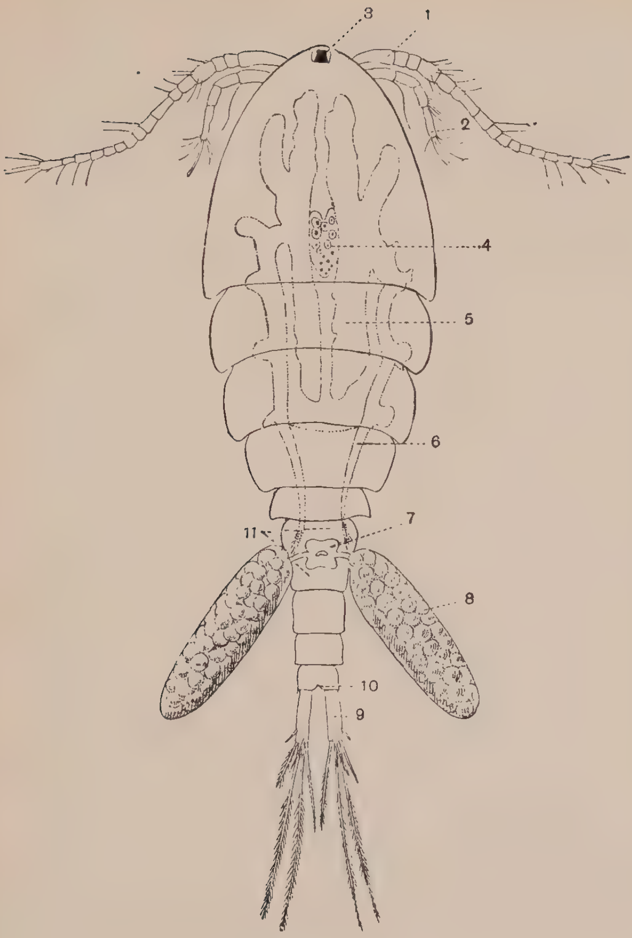



FIG. 23.—Dorsal view of female *Cyclops*.
(Partly after Hartog.)

1. First antenna. 2. Second antenna. 3. Eye. 4. Ovary. 5. Uterus, *i.e.* pouch of the oviduct into which the eggs pass before being shed. 6. Oviduct. 7. Spermatheca or pouch for receiving the spermatozoa of the male. 8. Egg-sacs. 9. Caudal fork. 10. Position of anus. 11. Compound segment, consisting of the last thoracic (bearing the genital opening) and the first abdominal.

The first abdominal segment in the female is fused with the last thoracic, which bears only the merest rudiments of limbs. On it open the oviducts and the small sac which is destined to receive the spermatozoa of the male. There is no heart in *Cyclops*, and the movements of the blood are brought about by the movements of the various parts of the body. There are a pair of glands which act as kidneys lying in the head, and opening at the base of the second maxillae. The alimentary canal is simple, and when looked at from above is rather occluded by the uterus in which the eggs rest for a stage on their way to the outer world.

The nervous system consists of the usual big ganglion above the mouth, a nerve-ring round the mouth, and a chain of ganglia running along the middle of the under or flattened surface. I do not know how many ganglia there are. There is no kind of auditory organ, but certain of the hairs on the antennae seem to be olfactory in nature. There is a single median compound eye, probably the result, as in *Daphnia*, of the fusion of two larval eyes. It is from this feature that the creature has taken its name. In classic times there were two races of *Cyclopes*: one of them helped Vulcan at his forge in the heart of volcanoes, especially in Mount Etna and on Lemnos. They were so strong that Kronos confined them underground, but Zeus set them free, for they furnished him with thunder and lightning. Later they appeared as the builders of cities

constructed of huge stones, which form of architecture is still known as Cyclopean. The second race mentioned in the *Odyssey* were a "froward and lawless folk", as Homer tells us, who lived alone in caves with huge herds of sheep and goats. Like the others, these had only one eye. This race seemed to be in some way connected with Neptune and the forces of the sea.

## Propagation

The ovaries are in the middle of the front part of the body, and the ovaries at each side tend to fuse together as they do in the crayfish and lobsters. They open into two large uteri, which are distinct from one another and occupy a considerable portion of the inside of the body. For a time the eggs rest in them, and then pass back through the thoracic segments along the crinkled oviduct, which opens just behind the last pair of paddle-like appendages. They pass out into two egg-sacs, and these egg-sacs, often most brilliantly coloured, are eminently characteristic of the group Copepoda. They occur even in those forms which have been most deeply modified by parasitism. Each egg-sac contains four or five dozen eggs which are compacted together by a mucus secreted by the female. In the same segment there is a small squarish chamber which opens in the middle line to the outside, and by two lateral ducts into the ovisacs. This is the spermatheca or pouch which, after fertilization, contains the spermatozoa of the male,

and the side ducts probably indicate that the eggs are fertilized in the egg-sacs.

We have seen that the *Cyclops* consists of five segments fused together as the head, five segments of which four bear paddles in the thorax, and four segments in the tail, making fourteen altogether. When the eggs hatch out they produce a larva of a form which is eminently characteristic of the Crustacea, although it is not common in the higher and larger forms.

This larva, called a *Nauplius*, is a tiny creature with three segments only, bearing three pairs of limbs which correspond with the first and second antennae and the mandibles of the parent form. It is a case of arrested development: the *Nauplius* has stopped short too soon, and in the course of time it will gain its full complement of segments. Thus for a time the young larval *Cyclops* represents the first three segments of the adult. When they were first discovered—and this was in the case of the group we are dealing with—they were believed to be adult, but it is now known that they cast their skins several times and add successive segments until the complete number of fourteen has been produced. The new segments always appear between the last-but-one and the last segment of the abdomen or tail.

Copepoda are extremely common in the sea, and in the Baltic region certain forms of the group are found in brackish water. Many of the marine forms have amazing beauty. Their hairs are produced into the most wonderful feather-like

structures. They have adopted most gorgeous colour schemes, the colour being generally confined to certain oil drops symmetrically arranged which have taken on the most brilliant hues. They are as beautiful as birds of paradise, or as Mr. Brock's fireworks at the Crystal Palace. Yet their glory is concealed, for you can see them only with the microscope. It seems a pity that so much splendour and radiance is lost to the world.

The number of Copepods in the sea is prodigious. They are by far the most abundant of all the metazoan (animals other than protozoa) animals which live in the ocean. There may be more unicellular organisms but these are so small that many thousands of them would be required to make up the bulk of an average-sized Copepod. Copepods in their turn are smallish creatures about one-sixteenth of an inch in length. They occur in all the waters of the globe, and hardly ever is a tow-netting taken up which does not include some members of this group. A few are found feeding on the mud, but the great bulk of them are pelagic, living near the surface of the sea. Most of them live on an average only seven or eight days. It has been calculated that in ten cubic metres of the Baltic Sea there is produced annually 8,866,000,000 of these little crustaceans, and as their numbers do not increase, presumably the same number are eaten every year. These calculations, however, are rather speculative. But they may be checked by the stomach content of the herring, which lives very largely on Copepods.

They are extremely nutritious and contain 59 per cent of proteins, 7 per cent of fats, 20 per cent of carbohydrates, 4·7 per cent of chitin (*i.e.*, their outer skeleton) and 9·3 per cent of ash. In nutritive value they are equal to the oyster, whose chemical composition most closely resembles theirs, and they are full of vitamins. They are positively phototropic (*i.e.*, they make their way towards the light). When taken and boiled they turn a vivid red like lobsters, and if spread on hot buttered toast and eaten with a little salt and pepper they are as palatable as shrimp paste ; indeed, they would make a very good food for human beings were their capture for that purpose a commercial proposition. They are emphatically a large source of food of fishes.

If on a voyage you tie a piece of bolting cloth loosely to the bath tap which introduces the salt water into the bath, in a very short time you will find a deposit or paste at the bottom which in the main consists of Copepods.

They are not equally abundant in fresh water, but still they are common enough, and Brady, writing seventy-five years ago, tells us that "the ordinary water with which the inhabitants of London are supplied for domestic purposes often contains them in large quantities."

CHAPTER XII

# OSTRACODS

*These minute Crustacea act as the scavengers of our seas and fresh waters. Some forms have been found as fossils as far back as in Cambrian rocks.*

THERE is a group of minute Crustacea seldom exceeding a millimetre or so in length known as Ostracods, and when ostracods occur in large numbers they act as the scavengers of the sea and fresh water, for they eat up dead and decaying organisms, and in this way prevent the poisons of decay spreading through the aqueous medium. Of all Crustacea they have the smallest number of appendages, and their body is usually unsegmented or only faintly segmented. A common species of ostracod in the fresh water of our islands is *Cypris*. It has a body flattened from side to side enclosed in two lateral shells which recall those of a mollusc. In fact, the word ostracod means " shell-like ". In some respects the animal resembles *Daphnia*, but the head never protrudes beyond the valves of the carapace or shell, and there is usually a special notch through which both pairs of antennae can be protruded. The shell is opened like that of a fresh-water mussel by an

elastic ligament on the upper or dorsal surface, and it is closed by the contraction of a muscle which runs across the body from shell to shell. The position of the attachment of the muscle to the shell is often of systematic import. The surface of the shell may be smooth or sculptured and it may be beset by little bristles. In one group each valve of the shell is well supplied with glands. The edges of the shell are free both in front and behind and all along the under surface.

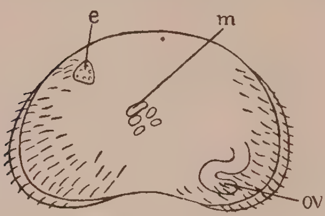



Fig. 24.—An external view of *Cypris*.

(*e*) Median eye; (*m*) Adductor muscle; (*ov*) Ovary. (After Gerstaecker.)

## Swimming Mechanism

Some forms swim freely by the lashing of their first antennae, which may be provided with olfactory hairs. The second pair of antennae also take a prominent—perhaps the most prominent—part, in swimming. These appendages resemble legs and end in strongly hooked bristles by means of which the animal can attach itself to surrounding objects. The third pair of appendages are the mandibles, usually with broad-toothed biting edges. In other forms, however, the mandibles have the form of legs rather than jaws; and in a few rare cases they take the form of styles which are enclosed in a sucking proboscis formed by the

upper and lower lips. The mandible often has a palp or sensory process attached to it. The first maxillae may be jaw-like or leg-like. The second in one large family, the *Cypridinidae*, carries a very large respiratory plate. Behind that the sixth pair of appendages may be either jaw-like or leg-like or absent, whilst the seventh pair of appendages are either leg-like or absent. In those

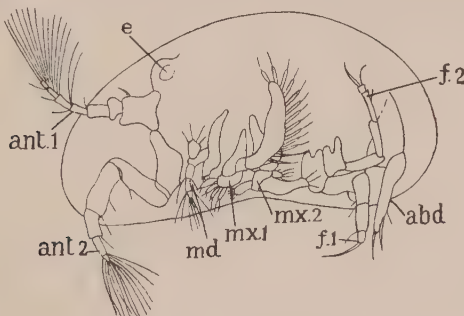



FIG. 25A.—An external view of *Cypris*.

With the appendages exposed by the removal of the left valve of the shell. (*abd*) Abdomen; (*ant.* 1, *ant.* 2) Antennae; (*e*) Median eye; (*f.* 1, *f.* 2) Thoracic feet; (*md*) Mandible; (*mx.* 1, *mx.* 2) Maxillae. (After Gerstaeker.)

species in which there is an eighth pair of appendages the latter frequently take the form of the male organ for introducing the spermatozoa into the female. The remainder of the body is rudimentary and ends in two processes forming a caudal fork.

## Microscopic Anatomy

Another point in which ostracods differ from the Cladocera, which includes *Daphnia*, is the fact

that some of the internal organs of the body extend into the space between the double flaps which form the right and left shells; the ovary, the testes and branches of the liver or digestive gland are prolonged into the valves of the carapace. Ostracods as a rule progress by swimming, and although the second antennae take the chief part in this form of locomotion both antennae are used, and this again is different from that which occurs in *Daphnia* and its allies.

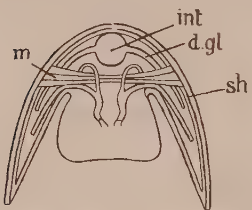



Fig. 25b.—Transverse section of *Cypris*.

(*d. gl*) Digestive gland; (*int*) Intestine; (*m*) Adductor muscle; (*sh*) Shell. (After Gerstaeker.)

The nervous system is typically crustacean, consisting of a bilobed ganglion above the gullet, a large ganglion below the gullet which supplies nerves to the mandibles and first maxillae, and a short chain of nerve-centres or ganglia running along the under side of the body. A few ostracods are blind, but as a rule the single median eye of the larval or nauplius stage is retained, and in the *Cypridinidae* there is in addition a compound eye on each side made up of from four to fifty or so separate elements. There are in addition olfactory hairs.

The mouth leads into a narrow gullet which opens into a dilated crop. In one genus there is an interesting foreshadowing of the gastric mill of the crayfish or lobster. This takes the form of hardenings or thickenings which are used in masticating

the food. The crop opens into the stomach and the stomach receives the secretion of the liver, part of which, as we have said above, lies within the two walls of the right and left shells. There is a short intestine which opens either above or below and in front of the caudal fork.

Some species have a heart, but other species are heartless. When present it lies on the upper surface near to where the shell fuses with the body. Apparently respiration is carried on by the inner surface of the shell as well as over the whole surface of the body. A regular circulation of water within the shell is kept up by means of the rowing movements of certain of the limbs. There are no outer gills as there are in the higher Crustacea.

## Gland Problems

There has been a considerable confusion about the excretory glands of the ostracods, and this confusion has recently been cleared up by the researches of Dr. Graham Cannon. Many years ago the great German zoologist, Claus, described a large gland lying between the lamellae of each shell which he traced into the base of the second antennae, though he could detect no opening. This he called the "shell-gland". Another pair of glands he described opened on the basal joint of the second maxilla. These did not penetrate into the shell. As a rule in Crustacea the excretory glands, which perform somewhat the same functions as our kidneys, are confined to those seg-

ments which bear the second antennae and the second pair of maxillae. But usually one pair disappears—for instance, in the crayfish the antennal gland or the so-called green-gland alone persists throughout life. In the smaller Crustacea, such as *Daphnia* and the ostracods, with which we are now dealing, the maxillary gland persists and the antennal one disappears. Cannon has pointed out that the so-called shell-gland of Claus is not really a true segmental excretory organ, and its function is unknown. The antennal gland consists according to him of an end-sac with a duct piercing through the bodies of three cells only, and then opening to the exterior. The entrance of the duct into the end-sac is guarded by a triangle of contractile fibriles occurring in the cells. This gland is at its maximum during the fourth larval stage, after which it loses its opening to the exterior and degenerates. On the other hand, the maxillary gland persists and it has an end-sac and a duct of four cells pierced by an intercellular duct. It also has a triangular arrangement of muscles forming a valve. The ducts are in all cases formed from the outermost layer of cells or the ectoderm, whereas the end-sac corresponds with the body-cavity sac of other Arthropods. The function of the shell-glands mentioned above, whose external opening has not yet been discovered, is unknown.

The sexes differ externally. There are always males and females, and they present well-marked structural differences. The male usually possess on one or other pair of appendages appliances for

holding the female, and there is a very large and complicated structure by which the spermatozoa are introduced into the body of the female. The testes are generally simple globular bodies which open by a common duct just in front of the hinder end of the body. In the *Cypridae* the testes present four rounded lobes and the two ducts are connected by a canal which may form a coil of great length. The most remarkable thing about the whole group is the enormous size of the spermatozoa which fertilize the eggs of the female. In *Pontocypris monstrosa* they may be three to seven millimetres in length, that is to say, eight to ten times the length of the whole body of the animal. In the female there are two ovaries, and oviducts; the former penetrate between the lamellae of the shell. There are two receptacula seminis where the spermatozoa are stored up, and these open at the base of the abdomen. The shape of the shell often allows one to discriminate between the sexes, and a male is always endowed with more sensory organs than the female.

CHAPTER XIII

# WATER-MITES

*Accurate details are still wanting in the life-history of this interesting group, which offers scope for investigation.*

"*Natura in minimis maxime miranda.*"—LINNAEUS.

MITES belong to the order Acarina of the class Arachnida (spiders, scorpions, etc.) and are, as their name indicates, small; but what they lack in size they make up in numbers. Indeed, mites seem to occur almost everywhere, though they are but seldom observed. Many of them are parasitic, belonging to the class of external or ecto-parasites which inhabit the surface of the body. The well-known *Sarcoptes* produces the disease known as the "itch", which was so troublesome amongst the army in the late war. Another mite that infests the human skin is an elongated creature which lives in the ducts of the sweat-gland and produces a minute black spot, generally on the nose or the ear. So widely is this little grub-like creature distributed that enthusiasts declare that it is probably the most widely known parasite of the human body. Other mites, such as *Phytoptus*, cause those conical galls so common on the leaves

of lime trees, maples, etc. Others, again, live amongst decaying organic matter such as cheese, and the common cheese-mite *Tyroglyphus siro* is perhaps as well known as any other member of the order.

### Mites and Museums

I have myself found mites running about in the air-sacs of a pigeon, and they are a perpetual nuisance to those responsible for our museums, inasmuch as they infest the cases in which the specimens are stored, and devour the linings of the contents. One of the most irritating mites is the well-known "harvest-mite", a little scarlet creature which attacks the human body and causes intense irritation. The "harvest-mite" appears to be the larva of a Trombidium, and probably many species of Trombidium produce this irritating ecto-parasite. A large number of mites are predaceous, feeding on insects and members of their own group. They are most troublesome in the autumn time where these larval forms swarm over the grass ready to attack any warm-blooded animal. Many mites live by sucking animal or vegetable fluid, and for this purpose they have a proboscis which is inserted into the skin of their hosts.

Mites have segmented bodies, and are members of the great group of Arthropoda, which include all the Crustacea, the innumerable insects, and a group called the "Arachnida". This last-named group includes the spiders which have a soft,

unsegmented abdomen, a number of spinnerets for spinning their webs, and a body with a waist. The Arachnida also include the so-called harvestmen, which have no waist, the scorpions, and the curious marine creature known as the king-crab.

## Under the Microscope

The mites also belong to the Arachnida and are characterized by an absence of waist and an unjointed abdomen, and by the presence of typical *tracheae* such as we find in an insect.

These *tracheae* are tubes which lead from the surface of the body and ramify throughout all the tissues. They are filled with air and so carry oxygen directly to every cell in the body. Tracheae are only found in Arthropoda which live on land or in fresh water. In most other animals, including man, oxygen is absorbed by lungs or gills and is there dissolved in the blood, by which it is carried to the cells of the body. In animals with tracheae this function of the blood as a "middle man" has been superseded and the "raw material" (oxygen) is conveyed direct to the consumer (the tissues). Tracheae are easily seen under the microscope if the tissues of an insect are squashed between two thin pieces of glass. The tracheae, however, may be absent in mites, and in that case the little creature breathes through the general surface of its body. There are also numerous free-living mites which enjoy

a place in the fresh water and in the sun, and it is these which we must now try to pursue in our chase for animal life under the microscope. The Hydrachnidae are fresh-water mites whose legs are provided with long, closely packed hairs adapted for swimming. They are predaceous and in their earlier stages, like the red spider, the larva is frequently parasitic, and in that case it lives on the body of fresh-water insects or on fish. These little creatures sometimes spread into brackish water, and one or two become marine. They help to keep down the fauna of the fresh water, feeding on infusoria, mosquitoes and larvae, daphnia, cypris and cyclops. There are somewhere about 400 different species recognized, and we propose to confine our attention to the species Hydrachna. They were first observed by Swammerdam, whose observations and drawings were published by Boerhaave in 1737. He found living on a water scorpion something that looked like an egg (*v.* Fig. 29, A): this on being opened revealed a mite. The group is not really very well known, for in the majority of cases the description is limited to the adult, and anything like an accurate life-history has yet to be made out in detail. This would afford a favourable subject of study to anyone interested in water animals. The research would not be easy, for it is a wise mite that knows its own father, and to connect the larval form with an adult is not easy.

Water-mites have a more or less flattened

body, something like a very thick outside slice of an apple. The skin is either soft, or it may be entirely or partly covered with hard chitin. There are usually four eyes in pairs, and between them lies the so-called unpaired eye, such as is found in some of the more rudimentary Crustacea. The appendages of the Arachnida differ from those of an insect. There are, to begin with, no

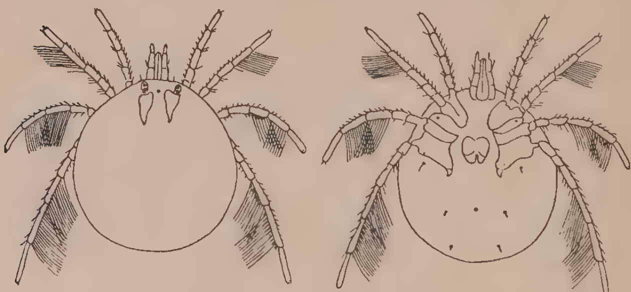


FIG. 26.[1]—Water-mite.

A (*Left*)—Water-mite *H. Globosa*, viewed from above, showing the three hinder pairs of legs with swimming hairs, two pairs of lateral eyes, median eye, and the proboscis or mouth parts.
B (*Right*)—View of the under side, showing the plates supporting the eggs, the mouth parts in front, and the genital plate in the centre.

antennae, and there are no true biting appendages or jaws. The first pair of appendages are called the pedipalpae and the second pair the chelicerae. These may be surrounded by an extensive proboscis, and between their bases the mouth opens. The adult form has four pairs of legs, and the larva only three. The legs have six joints or segments, and are attached to plates in the ventral

[1] The figures in this article are re-drawn from Soar and Williamson, *Ray Society Publications*.

or under side of the body (*v.* Fig. 26, B). The tracheal system for breathing may be present or it may be absent, and the external differentiation of sex may occur or again may be absent.

If we take as an example of these minute fresh-water arthropods *H. globosa*, we shall find that viewed from above the outline varies from a broad oval form to a rather remarkable elliptical one (Fig. 26, A). Probably the outline varies with the ingestion of food. The length of the body is two or three millimetres, and it has a brilliant red colour, a regular cardinal's red, which deepens in tone as the animal ages. Just behind the head are two thickenings forming two triangles with the pointed ends projecting backwards. In connexion with these are two hairs, one at the hinder end, the other at the outer front angle. The eyes are double, two on each side of the median line, and slightly behind and midway between them the fifth or unpaired eye can be seen.

In the Hydrachnidae the pedipalps are usually five-jointed and elongated, the terminal joint being bent backwards to form a grasping organ (*v.* Fig. 27, B). The chelicerae also usually have a terminal claw. In those members of the group which have breathing organs the tracheae open by a pair of spiracles on the dorsal side of the rostrum, which is slender and usually straight. It hardly extends beyond the joint of the fourth and fifth segment of the pedipalps, which are about 1·2 mm. long, and are slightly laterally compressed. The base of the segment is strongly developed. The thicken-

ings on the dorsal side of the body are shown in Fig. 26, A, which also includes the double eyes almost fused around the single median eye. Fig. 26, B, shows the lower or ventral surface with the thickenings which support the median genital plate; these are seen in detail in Fig. 27, A. All these have value in the systematic classification of the group. Fig. 27, B, shows the enlarged pedipalp of another species. The first pair of legs vary from 1·2 to 1·8 mm., the second from 1·5 mm. to 2·24 mm., the third 2·1 mm. to 2·4 mm., the fourth and last pair 2·22 to 2·8 mm. in length. The last three pairs have numerous hairs which aid in swimming. Some of these are pectinate. The claws at the end of the legs are sickle-shaped. The anus is about 0·4 mm. behind the genital pore, around which are a number of bristles and certain sucker-like organs known as acetabula.

One common genus of water-mite is found in almost all fresh-water mussels. In fact, it is hardly possible to dissect an Anodonta without finding on the mantle or foot or gills one or more specimens of a small black-and-white mite known as *Atax bonzi*. This, and another species, *Atax crassepes*, are really not two parasites, but rather *commensals* living on the food supply brought into the shell of the fresh-water mussel by the action of its cilia. These two mites pass their entire life in connexion with mussels, leaving one individual only to find another, where they may be seen running about over the ciliated surfaces. The second species, *Atax crassepes*, finds its host after

the second larval stage and lives freely when adult. Both species lay their eggs in the gill tissue of the mussel, and here it is that the larval metamorphosis takes place. But in the intervals between casting its skin it may quit the gill chamber and wander about the body.

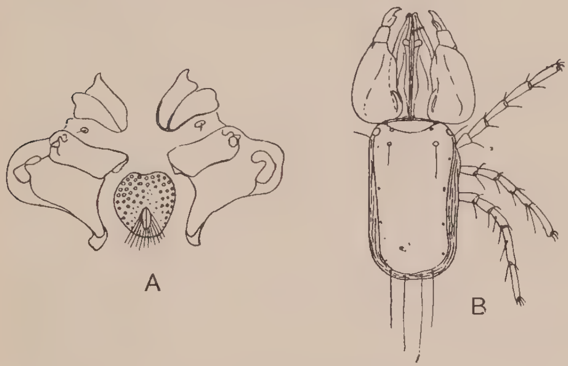



Fig. 27.—Water-mites.

A (*Left*)—The genital plates of a water-mite (seen in Fig. 26, B) more highly magnified. The central reproductive plate is supported by thick chitinous plates of irregular shape.
B (*Right*)—The larval form of another species of water-mite, seen from above, showing clawed mouth parts, which in this species are very much enlarged.

The eggs of water-mites are laid in or on submerged plants. In *Hydrachna globosa* the egg-laying takes place in May. The female pierces the tissues of a plant with her rostrum ; and this species apparently does not surround its eggs by a gelatinous coating. In most species, however, the eggs are laid on the outside of some stalk or leaf (Fig. 28), and each egg is surrounded by a gelatinous layer which is fused into a common

mass so that in a way the result is somewhat similar to frog's spawn. In this mass the young mite grows and can be seen developing. In certain insects there is a phenomenon known as hypermetamorphosis, that is to say, the insect is not content with four normal stages—the egg, the

FIG. 28.—Eggs of Water-mites.

(*left*) laid on the under side of a leaf ; (*right*) in the stem of a reed.

larva, the pupa, and the imago or adult—but passes through a series of larval forms which differ through a greater or less degree. The same is the case with mites. Young larvae which emerge from the eggs have three pairs of legs, the fourth pair only appearing at a later moult. And until the last stage of all of the adult the genital pair is not complete.

The sexes are always separate and may generally be distinguished one from another, and all species lay eggs. There is no other method of reproduction. Soon after the three-legged larva has hatched, in most cases it attaches itself to some aquatic insect (Fig. 29, A) to which it hangs on like a minute drop and from which it absorbs its nutriment. They also infest young fish (Fig. 29, B). During this parasitic stage the larval appendages have dropped off, and the animal comes to resemble a pupa which increases greatly in size as it feeds on its host. From this the pupa-like stage develops an active eight-footed nymph possessing four pairs of legs and palp, which are quite similar to those of the adult. This nymph stage is usually a free-living one, and another moult must occur before it becomes adult. This last moult, however, is not delayed, and may occur whilst the mite is hanging on to water plants.

Water-mites have little economic value beyond the fact that they serve as scavengers, acting like the ostracods in the sea, and they also form the food of other animals. Of course, during the time they are living on their hosts they doubtless injure them to a certain extent, but they do not seem to be fatal. It is scarcely ever to the advantage of a parasite to kill its host and thereby destroy the goose that lays the golden eggs. At times mites are found in considerable numbers in the stomachs of fish. They are as a rule fairly active, swimming at a fair speed, or walking more slowly over the bottom of a pool or climbing about

amongst plants and other objects. At times they rest, and if disturbed seek refuge in flight. They have not been much studied, but seem to be pretty generally distributed over the world, and they show a preference for clear, cool water, rich in plant-life. They are found in all seasons of the

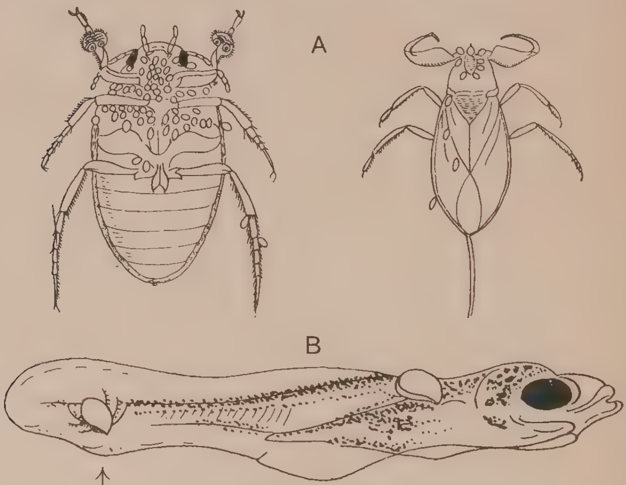



FIG. 29.—Parasitic larvae of Water-mites.

A (*Above*)—Parasitic larvae of water-mites, seen (in appearance like eggs) attached to two species of aquatic insect.
B (*Below*)—Three-legged larva infesting young fish (on the left, above arrow).

year, under the ice in winter, and appear most abundantly in the early spring, becoming adult during the latter part of the summer or autumn. In Great Britain one or two other species have been found almost wherever they have been sought.

They are not a particularly popular form of

animal life, although to the enthusiast they are quite irresistible. Pope in his *Essay on Man* seems to sum up the common feeling about these obscure and imperfectly known Arthropods :

> Say what the use, were finer optics giv'n,
> T' inspect a mite, not comprehend the heav'n.

CHAPTER XIV

# THE LARVAE AND PUPAE OF MOSQUITOES

> Then in a wailful choir the small gnats mourn
> Among the river sallows, borne aloft
> Or sinking as the light wind lives or dies.
>
> "To Autumn," KEATS.

YOU can easily see the larvae of gnats or mosquitoes with the naked eye, but without a microscope you cannot see the details which make these little creatures so extraordinarily interesting to watch. The larvae of both these insects hang on to the surface film of the water in which they live, and are easily frightened away from it and sink to the bottom, and both swim by means of a waving motion of their body. But the waves are short and jerky; they have none of the voluptuous appearance of a leech swimming by graceful undulations through the water. The larvae of *Anopheles maculipennis*, our commonest mosquito, issue from a little floating egg which, when deposited, is at first white, but soon darkens until it assumes the hue of a highly polished black surface divided up into minute hexagonal areas by almost imperceptible ridges.

## Scattered Eggs

The egg is boat-shaped and like a boat one end is slightly deeper and fuller than the other. Above the edge of the boat is a rim of little "cells" which, between the end of the first quarter of its length and the beginning of the last quarter, are greatly enlarged and are full of air. These act as floats and keep the egg the right way up. They somewhat resemble the floats which run round the edge of a lifeboat. The eggs measure from 0·7 to 1 mm. in length, and average about 0·16 mm. in breadth. Should the egg be in the neighbourhood of a floating leaf or near the walls of the containing vessel it will be slightly drawn up by capillary action, and then the blunt end which contains the head of the larva points downwards; and thus, when hatching takes place, the young larva is liberated into the water and not into the air. The eggs do not form clumps like those of the common gnat, but are apt to be scattered, at any rate in the open pools of Great Britain, and may easily be blown from one watery home to another. The female lays some hundred-odd eggs and always in water which is rich in vegetable matter; on this the young larvae will feed. They can be kept alive for months in dried mud, and can be found in dried-up pools in tropical countries. They take two to three days to hatch out, the period depending upon the temperature. At the end of this time a circular split occurs near the blunt end of the egg-shell and a cap falls off, but there is no

visible constriction at its base as there is in so many insect eggs.

## The Young Larva

The young larva emerges behind the cap and is at first very small, but in all its stages one can distinguish between (1) the head ; (2) the thorax ; and (3) the abdomen. The number of segments in the thorax is three, though they are very much fused together. The abdomen shows nine segments, the last of which is inconspicuous. The last but one bears the breathing spiracles. The head is like a sphere, a portion of which on the front and lower side is flattened and modified to bear the appendages of the mouth. It is of a deep brownish colour, and bears two pairs of eyes which are comparatively small. They are quite lateral and situate some way from the front, and they are of two kinds, one compacted of a number of lenses forming a circle, the other a number of single lenses scattered behind the circle. Between them on the upper surface are symmetrically arranged four branching hairs like the plumules of a bird. In front of the eye is a small prominence which bears the antennae, and between the antennae rest six feathered hairs placed at regular intervals, which hang over the front of the head like a halo. None of the hairs seem to move.

The most conspicuous organs in front and on the upper side are the so-called moustaches. These are a very conspicuous bunch of stout, dark-brown

hairs spirally arranged and slightly curved. They are as closely packed as are those of a shaving-brush, and at their base are other small hairs all converging on the mouth. These moustaches perform a very vital part in the life of the larva, for it is they that collect the food upon which it lives. They are moved by certain stout muscles, and it is very curious to watch them, sweeping up all the light organic particles which have

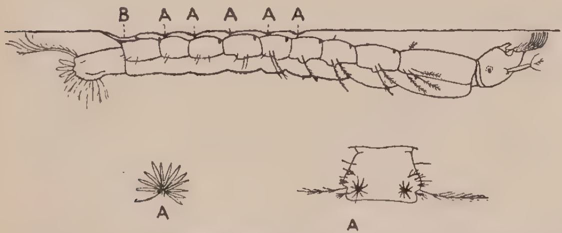



FIG. 30.—Larva suspended beneath the surface film by five pairs of palmate hairs marked A.

The surface film is pierced by the spiracle at B. The head is reversed through an angle of 180 degrees, and is brushing the lower surface of the surface film with its moustaches. The lower figure to the right is an abdominal segment showing the position of the palmate hairs. To the left is shown one of these hairs more highly magnified. The "buffer" hairs at the hind end of the larva are seen to the left.

floated up and are held by the surface film. These particles are swept together just beneath the surface of the film until, like the whalebone of a whale, the moustaches are packed with food. When the moustaches are sufficiently charged with nutriment they are suddenly folded under and swallowed by the mouth.

We shall return to this method of feeding when we have described the mouth appendages. The

head bears three pairs of appendages. (1) the antennae or feelers. These are two-jointed, though the first joint is very short and seems to be immovable and fixed to the covering of the head, and it may be it is a projection of that covering. The second joint is long and movable. It bears a few spines and its top carries two large spines which can be separated from one another and brought together again. On the under surface, lying on each side of the mouth, are (2) the mandibles. These are thick and hard structures, and are used for biting up and crushing the larger pieces of food. (3) Following on these is on each side a maxilla which bears a sensory process or palp. The maxilla itself is something like a flattened pad bearing on its upper surface a number of very short hairs, one half pointing one way and the other the other way. But both point to an intermediate zone in the middle of the pad. The edge of the pad is fringed with slightly hooked hairs. Now, when the moustache is swallowed into the mouth it is compressed between this pad and the upper surface of the mouth, and the hairs on the pad act like the projections on a carding-brush, combing out from the moustache all the organic particles which have been collected there.

Returning now to the moustaches and their action. Normally the larva lies under the surface film with its back against the lower surface of this structure. In this condition the moustaches and the mandibles would naturally be on the lower side pointing towards the bottom of the pool.

But the moustaches want to sweep the organic matter which has floated to the surface and is confined by the lower side of the surface film, and in order to allow them to perform their proper functions the whole head is turned through an angle of 180° so that whilst the dorsal side of the body lies uppermost when the larva is feeding, the ventral side of the head also lies uppermost. This reversal of the head occurs quite suddenly. The whole thing revolves with such extraordinary precision that you almost expect to hear a click as it comes into position. As soon as that is accomplished the brushes are bent backwards and inwards, and in this way a current is set up, sweeping the suspended food particles in convergent curves towards the mouth. The moustaches are then bent back either simultaneously or singly, and they are frequently swallowed again and again, and the movement may be very rapidly repeated —one hundred and eighty times a minute is recorded. The distance to which the currents are set in motion by the action of the brushes extends at least twice or three times the full length of the larva. The whole process is very fascinating to watch under a fairly low power of the microscope.

The food actually consists of particles of the simple plant *Spirogyra*, diatoms, and any other minute organisms which cannot pass through the surface film. Occasionally a larva attacks decaying leaves of duckweed (*Lemna*), but as a rule the food consists of protozoa and unicellular algae. The content of the alimentary canal is frequently

green. At certain times food which the larva cannot swallow is brought towards the mouth, and after a struggle is rejected. A mouth full of food gradually accumulates, and then with a sudden gulp is swallowed down into the oesophagus or gullet. That the surface film entangles food is shown by the fact that some fresh-water snails and certain turbellarian worms browse over the same area, which as a feeding ground is by no means unworthy of notice.

## Thorax and Abdomen

Behind the head and separated by the reversible neck comes the thorax, which has no marked divisions separating the three segments of which it is built up. It is decorated with a certain number of feathered hairs, and is markedly broader than the other regions of the body. Then comes the abdomen of nine segments, bearing again numerous feathered hairs. The third, fourth, fifth, sixth, and seventh segments bear a pair of palmate hairs on their upper surface. These are like the ribs of an umbrella turned inside out, and they play an important part in the life of the larva. Each hair has a stalk, and it is these palmate hairs that keep the little larva in position under the surface film, for the tips of the hairs cling to the surface film just as a waxed needle does. The larva may suddenly lose its purchase and sink, in which case these palmate hairs not infrequently carry a bubble of air to the bottom.

On the eighth abdominal segment lie the external openings of the respiratory system, separated by a rather complex external skeleton. These spiracles, as they are called, pierce the surface film and through them the tracheae are put into communication with the outer air. Occasionally the

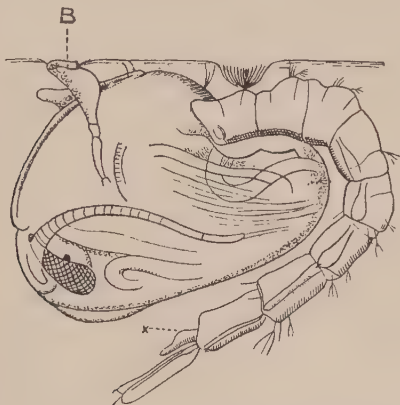



FIG. 31.—Pupa suspended from the surface film by a palmate hair.

The eye, the antennae, some of the mouth parts and the legs can be seen through the semi-transparent pupal case. The abdomen is folded under the head and thorax. The surface film is pierced by the spiracle at B.

anterior end of the body is twisted round and the larva begins to clean with its mouth organs the complex respiratory apparatus, which sometimes seems in danger of being clogged with debris. When they leave the surface film the larvae sink by their own weight, and they have to swim back in an eel-like manner to regain their normal

position. They move tail-forward, and the long caudal hairs undoubtedly act as buffers.

### Rate of Development

The larvae of gnats (*Culex*) differ from the larvae of mosquitoes (*Anopheles*) by the fact that their spiracle is borne at the end of a long process and their body, instead of lying parallel to the surface film, hangs at an angle from it. The larva of *Culex* are more readily frightened than are those of *Anopheles*, and are reluctant to return to the surface when they have sunk to the bottom. Having no limbs swimming has to be done by the movements of the body, and these are such that the common name for the larvae is wrigglers. They grow fairly quickly. At birth they are 0·9 mm. in length, but by the twelfth day they have attained a length of 4·3 mm. They cast their skin periodically. When they are full-sized they attain a length of about 7 mm. and then they usually pupate. But the rate of development is very dependent on the temperature, and a few cold days retard their growth, and a considerable number of larvae perish during the process of development. This may be partly due to the natural difficulties of moulting or to the destruction by natural enemies. Under ordinary conditions very much larger numbers of small larvae are found, the small larvae being much more abundant than the large ones. Out of a total of 834 larvae and pupae collected at different

times in six places in Cambridgeshire 636 were small larvae, and only 181 were large, measuring up to 7 mm., and only 17 pupae were captured. No doubt a certain number eluded capture, but these figures with others tend to show that many die off in the early stages of their existence.

## The Pupal Stage

The larva which is about to become a pupa comes to rest. Its thoracic region becomes greatly swollen and finally a slit appears in the cuticle, above the centre of the upper side of the larval casing, through which the pupa gradually issues, leaving behind the chitinous appendages of the larva. The young pupa measures some 6·5 mm., of which the head and thorax occupy about two-thirds. Later their relative sizes increase. The whole structure is rather like a tadpole if the tail of the tadpole were flattened from above downwards and folded along the under side of its body. Many of the pupal organs are formed during the last stage of the larval life. The spiracles now lie further forward, and terminate in two trumpet-shaped stigmata arising from the anterior upper surface. These are the only external openings, for the alimentary canal is shut and the whole organism "is closed for alteration and repairs". Already in the freshly issued pupa the eyes are conspicuous and black. The antennae are there, folded backwards. The mouth parts are long and coiled symmetrically and show no relation to the

mouth parts of the larva. The legs are apparent and the sex can be already determined by the shape and relative size of the plates at the hind end of the tail.

The pupa is suspended on the surface film by two pairs of radiating hairs resembling the ribs

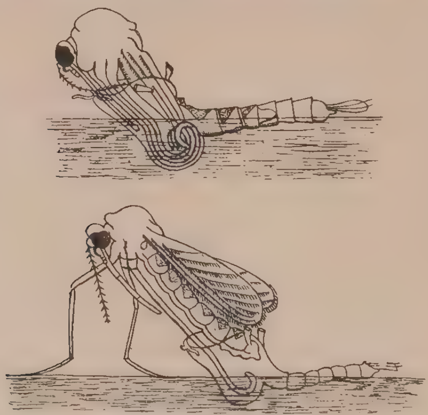


FIG. 32.—Two stages of the imago extracting itself from the pupal case.

The upper figure shows the beginning of the process, the lower shows everything extracted but the third pair of legs. The mosquito is standing on the surface film with its front four legs.

of an umbrella which has been blown inside out. The spiracles pierce the surface film. As it grows older the pupa darkens, becoming a deep brown or sometimes green.

Until it is about time to give rise to the imago or mosquito the pupa floats quietly on the surface until disturbed, when it shows considerable activity and, indeed, is rather difficult to capture. It darts rapidly to the bottom of the vessel in which

it is contained, and will after a short time rise again passively, it being extremely buoyant. After a time, varying from three to four days, according to the temperature, a split will appear along the top of the head, and from this the imago will gradually emerge, dragging the head and body slowly out. The legs follow, and finally the abdomen is freed, and the newly issued insect, often standing on the surface film of the water, like St. Peter, slowly stretches its wings and prepares for flight.

### A Critical Moment

The emergence of the imago is a very dangerous operation. The exit of the mosquito is a critical moment in its life-history, and a large number fail to extract themselves from the pupa case. Indeed, the birth of the perfect mosquito recalls that of Edward Gibbon, who mentions at the beginning of one of the drafts of his autobiography "after nine months of an aqueous existence I was painfully transported to the outer world". But, of course, the period of incubation of a mosquito is far less than that of the author of *The Decline and Fall of the Roman Empire.* The first part to emerge is the thorax, and thence onwards the animal seems to "grow" without visible effort out of the pupal covering. The abdomen of the pupa is now parallel with the surface film of the water. Gradually the head and the abdomen emerge and the pupal skin remains increasingly filled with air. It is of the utmost importance for

it to keep close to the surface film, so that the perfect insect may be born not into water but into the atmosphere. The head is pulled backwards and then upwards and then with its mouth parts, palps, and antennae gradually gains freedom. The wings come away easily, but the legs present difficulties. The front legs are first freed and the tarsal extremities of these now rest upon the surface of the water. The abdomen by this time becomes completely free, and the tarsal end of the second and third pair of legs are withdrawn with a rapid succession of short, jerky pulls. The mosquito is now freed. It has attained a place in the sun. At first it does not seem to think much of it, for it is rather tremulous and weak, but soon it fills up its trachea with air, the wings become flattened out and firm, and it is able to fly away to feed and to seek a mate. Reckoning from the moment when the thorax first appears the fly usually frees itself, if undisturbed, within from five to ten minutes. A number, however, die in the first stage from a failure to free their head, and they may die during the succeeding stages by failure to free the abdomen or the legs. So violent is the effört to tear the legs loose that not infrequently one or two, and in one case three, of the legs were left behind in the pupal case.

## The Young Imago

The young imago is pale in colour, the thorax being a pinkish brown, the abdomen translucent

and green, the legs pale brown, with characteristic spots on the wings which are visible on their dorsal surfaces. The abdomen is at first very long, but it soon begins to retract, this process being accompanied by the expulsion of some clear, glistening, greenish drops. Within about five minutes it has assumed its normal size, and the perfect insect can fly away in five to ten minutes after it has left the pupal case. Before that, however, they can only move away by means of their legs. If they attempt to fly they frequently fall in the water and drown. In a very short time the young mosquito begins to darken, and after two hours or more it is normal in its coloration. Should anything prevent the insect from extending its limbs during the metamorphosis or immediately after it has issued from the pupa case, the parts harden and remain distorted.

CHAPTER XV

# SIR RONALD ROSS AND THE MALARIA PROBLEM[1]

Now I will explain to you what the law of diseases is, and from what causes the force of disease may suddenly gather itself up and bring death-dealing destruction on the race of men and the troop of brute beasts.—LUCRETIUS, *De Rerum Natura.*

SIR RONALD ROSS has written a full-dress autobiography, and he has written it very well. It is, as he tells us, intended for the general reader as much as for the medical man for, as he states, it is the laymen and not the doctors who rule the world.

Sir Ronald Ross is very justifiably full of divine indignation at the way in which the works of science are neglected by our politicians and legislators. A typical example of this occurred but a few months ago. Westminster Hall with its restored roof was reopened by the king, many speeches were made and many articles were written dwelling on the history of that noblest of Halls, and on the many dramatic episodes that had taken

[1] *Memoirs: with a Full Account of the Great Malaria Problem and its Solution.* By Sir Ronald Ross. (John Murray, London, 14s. net.)

place in that stupendous building, yet, so far as I know, not a single speaker and not a single writer referred to the gifted entomologist who had made the restoration of the roof and the preservation of its old timbers possible. Historians are notoriously bereft of a sense of proportion, and whilst in many articles they dwelt upon the great scenes that had been enacted in the Hall, not one of them even remarked on what was perhaps the most dramatic and most important scene of all, the finding by a distinguished Professor of Entomology of the London School of Science of the larvae of the beetles that had for decades been eating up the woodwork in the roof, and his still more remarkable application of a chemical compound which proved fatal to the beetle and all its works and made the beams whole.

Sir Ronald begins with his ancestry, which he deals with all too shortly. The Ross family had for some years been closely associated with India. Sir Ronald's father's commission in the Indian Army dated from 1841. From 1859 onwards the latter saw a good deal of service. His regiment, ordered up to Amritsar, then as now a danger spot, failed to receive the higher rate of pay which had been awarded to lower battalions. Consequently they mutinied, and the Commander-in-Chief disbanded the unit. Ross's father was then moved to Simla and on to the North-west Frontier and in time to the Kumaon Hills, where three days after the outbreak of the great Mutiny Ronald Ross was born. His first memories are of

mountains, snows, rhododendrons, and fir trees. In a notable paragraph the author draws attention to the fact that one can rarely remember anything of the first four or five years of one's life. "Is it possible," he asks, "that the child's brain-cells are changed and that he sheds his mind as he sheds his first teeth?" Yet it is true during these early years that the child learns to talk and to exercise a certain amount of self-control and judgment and to co-ordinate his movements, and it is certainly capable of reasoning, for it knows very clearly what it wants and by experience the best way to attain it. A typical instance of this failure of memory is the fact that Sir Ronald spoke Hindustani as well as English as soon as he could learn anything, but that on his return to India twenty-four years later he had forgotten every single word of the former language. When he was eight years old, in 1863, he was sent to England, where he lived with an uncle in the Isle of Wight. His education was rather miscellaneous and self-sought; but he immersed himself in the classics to such an extent that on one occasion his uncle exclaimed: "Why, the boy talks Elizabethan English!" As a schoolboy he seems to have had a considerable amount of leisure, which he largely devoted to zoological pursuits. He read the classics, but mathematics were his forte and his foible. He was no mean artist, having learned much from watching his father work on his admirable water-colour sketches, and in 1873 Ronald was bracketed first for Drawing in all England at

the Oxford and Cambridge local examination. Indeed he wished to become an artist; but his father was opposed to that, and being of a dreamy nature with a fondness for warm climates, he made no objection when his father insisted on his reading for the Indian Medical Service. He entered St. Bartholomew's Hospital in 1874 and was kept hard at work. In time he became dresser to Mr. Savory, a man of fine presence and dramatic oratory, but, as I remember him, a little vague about the aspirate. Whilst reading for his final examination, Ross took several voyages as a ship's surgeon, during one of which he wrote a whole Spanish drama, called *Isabella*. All through his life he has been constantly writing verse, blank or otherwise, plays, novels, with varying degrees of success. Having qualified early in 1881, he sat for the I.M.S., where he took the seventeenth place and began a course of special training at Netley, a place where he was thoroughly at home and very happy.

## Early Days in India

In the autumn of 1881 Ross reached India and there began the varied, if somewhat monotonous, career of an army doctor. He rejoices in the change of climate and the broad sunlight and the air of India. He was full of energy, thinking out problems of all sorts and going through a thorough course of the world's poets, studying Italian, French, and German, and returning again to the

Greek and Latin writers. He wrote a great amount of poetry and threw himself into the study of mathematics, in which subject he published several papers of recognized value. For a time he was stationed on the North-west Frontier, then he was transferred to Burma, the Andamans, and Madras. It was in the Andaman Islands that he wrote his first novel, entitled, *Child of the Ocean*. Then he moved to Madras, and here, after seven years' continuous work, he broke down. He was a bit discontented. Even now in his seventh year of service he had not yet received a "pukka" appointment, which meant the loss of 100 rupees a month. He had also been refused a year's furlough to England, to which he was entitled after five years' service. There had been mismanagement in the admission of candidates, and when Ross entered the Service in 1881 the junior ranks were overcrowded, with the result that numbers were drastically cut down, so that there were now no junior officers to take his place if he could be given leave of absence. He felt, as all men feel under such conditions, an intense yearning for home, its cold weather and its cloudy skies, and when in 1888 he eventually left for home, he soon became a different man. During his furlough he married Miss Rosa Bloxham, and on their return to India the following year he was sent immediately on field service to Burma, a country whose beauties he thoroughly appreciated. In 1890 he was put in charge of the hospital at Bangalore, and there he remained three years,

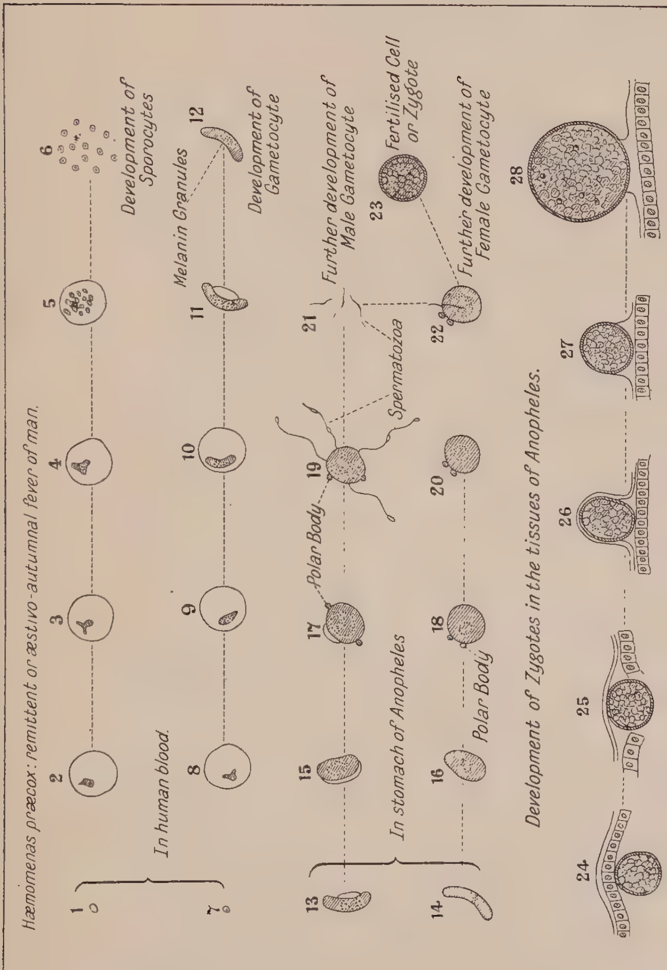



FIG. 33.—Life-history of the malarial parasite.

taking part in all the activities of the white man in an Indian Station.

In 1904 he was back again in Europe and had a great time in the Alps; but he really should not assign our well-known physician, Dr. Wherry, with whom he climbed, to the sister University!

Ross had attempted a great many things and achieved success in most of them; but he was neither satisfied nor entirely happy. He was now to embark on the great work of his life—a work which has brought him fame and honour, and which has done perhaps as much as any other contribution to science to relieve suffering and postpone death, and so make vast regions of our globe a fitting home for the white man.

Abraham Cowley foresaw it when he wrote:

> Th' excess of heat is but a fable;
> We know the torrid Zone is now found habitable.

On March 28th [1895] I departed again for India, leaving my wife and three children at home. My age was thirty-eight and I had attained the rank of Surgeon Major in 1893, after twelve years' service.

Ross is most scrupulous in assigning to others their just share of the work in clearing up the tangled subject of malaria. At the beginning of Part II. of his *Memoirs* he describes in detail all that has hitherto been known as to the problem of transmission of the parasite. He is just and fair all round.

On his return from India he suffered innumerable disabilities. He could obtain no systematic

works on mosquitoes. He was ignorant of the Romanowsky method of staining and, like everybody else, he was to a great extent searching in the dark. Finally, he was necessarily hampered by his routine work, and still more by the total inability of the higher authorities even to understand what he was trying to arrive at. Then, again, little or nothing was known about the structure of the mosquito's body, and to dissect these one after the other in a tropical temperature shows an amount of faith and devotion to the cause which is worthy of the highest praise. But for the cheering and inspiring letters of Sir Patrick Manson, the original suggestor of the mosquito-malaria theory, it is difficult to imagine how he could have stuck to his job.

## The Great Discovery

The actual discovery—the discovery which has indelibly engraved Ross's name on the roll of Fame—is best described in his own words :

The 20th August, 1895—the anniversary of which I always call Mosquito Day—was, I think, a cloudy, dull, hot day. . . . After a hurried breakfast at the Mess, I returned to dissect the cadaver, but found nothing new in it. I then examined a small *Stegomyia*, which happened to have been fed on Husein Khan on the same day (the 16th), which was also negative, of course. At about 1 P.M. I determined to sacrifice the seventh *Anopheles* (*A. stephensi*) of the batch fed

on the 16th, although my eyesight was already fatigued. Only one more of the batch remained.

The dissection was excellent, and I went carefully through the tissues, now so familiar to me, searching every micron with the same passion and care as one would search some vast ruined palace for a little hidden treasure. Nothing. No, these new mosquitoes also were going to be a failure: there was something wrong with the theory. But the stomach tissue still remained to be examined—lying there, empty and flaccid, before me on the glass slide, a great white expanse of cells like a large courtyard of flagstones, each one of which must be scrutinized—half an hour's labour at least. I was tired, and what was the use? I must have examined the stomachs of a thousand mosquitoes by this time. But the Angel of Fate fortunately laid his hand on my head; and I had scarcely commenced the search again when I saw a clear and almost perfectly circular outline before me of about 12 microns in diameter. The outline was much too sharp, the cell too small to be an ordinary stomach-cell of a mosquito. I looked a little farther. Here was another, and another exactly similar cell.

The afternoon was very hot and overcast, and I remember opening the diaphragm of the sub-stage condenser of the microscope to admit more light and then changing the focus. *In each of these cells there was a cluster of small granules, black as jet* and exactly like the black pigment granules of the *Plasmodium* crescents. As with that pigment, the granules numbered about twelve to sixteen in each cell, and became blacker and more visible when more light was admitted through the diaphragm. I laughed,

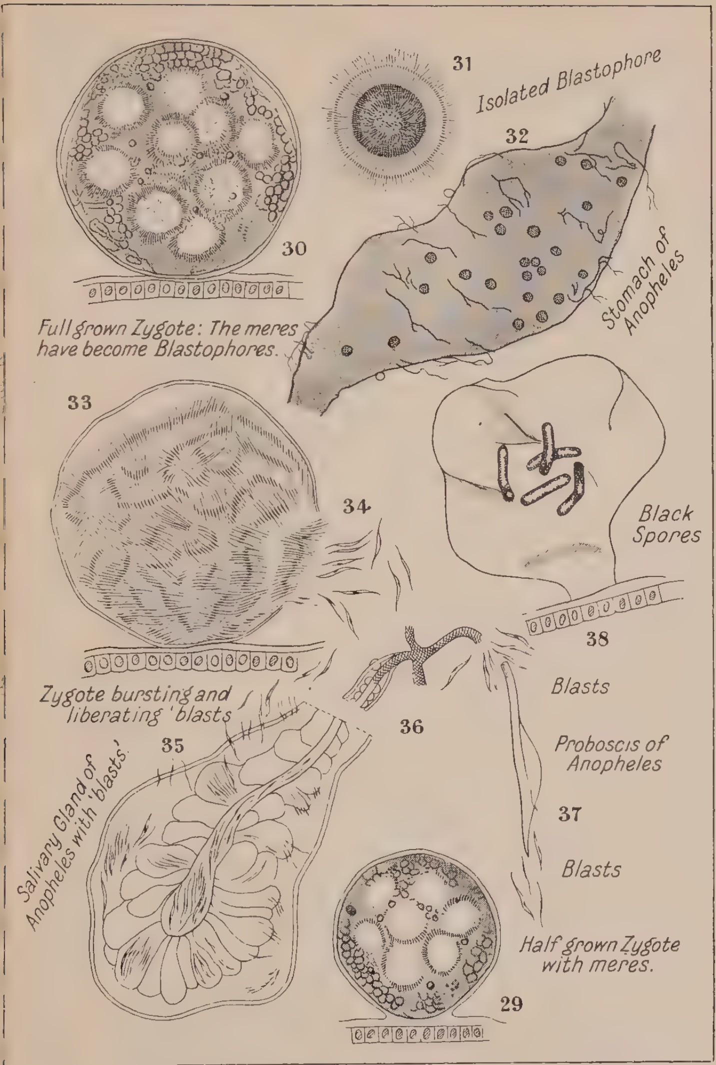



FIG. 34.—Successive stages in the development of the malarial parasite in the mosquito (*Anopheles*).

and shouted for the hospital assistant—he was away having his siesta.

This was the first discovery of the malarial organism in the body of the mosquito, and it was no chance discovery. There are hundreds of different mosquitoes in India, and Ross had been carefully dissecting hundreds if not thousands of these, not knowing which kind to investigate or where to look in the body for the parasite. Now he had found it, and he had made two discoveries simultaneously. He had found out the kind of mosquito which carries the parasite and the form and position of the parasite within it.

There was still, of course, much to be done. He held the key to the mystery, but the door remained to be unlocked. He had discovered the zygotes of the fourth and fifth day after infection, but what happened afterwards to the parasite had still to be investigated.

In 1898 Ross was compelled to carry on his research on the malaria in birds, as his superiors kept him away from areas where man was the victim of that fever. He now found the zygotes dividing up into innumerable spores and pressing their way through the coats of the stomach into the body cavity. By the middle of that year he was finding that these spores were more numerous in the thorax and the head than in the abdomen, and finally he traced them to the salivary glands, of which he gives a very convincing sketch. He now had definitely established that malaria is conveyed from a diseased person or bird to a

healthy one, and by the proper species of mosquito and no other.

He had solved the great problem.

On July 10, 1896, he wrote:

> I would better your suggestion that malaria is in the first place a disease of mosquitoes—hence the idea of its being carried by winds. It is the *mosquito* and not the *germs* which are carried by the wind.

At that time he thought the germs were probably deposited in drinking-water, which thus became infective. Ross was again gradually making progress when he was suddenly moved from Secunderabad to Bangalore. This was the first of three serious checks the Executive placed upon his work until they finally checked it altogether.

## Official Opposition

In 1897 he himself suffered from a severe attack of malaria. During this time he returned to Secunderabad and here again Fate stepped in and he was ordered (although it was not his turn for active service) to the North-west Frontier. He was working out the fate of the pigmented cells he had found in the mosquito, and was rejoicing over further proofs of the theory when he was ordered to a non-malarious district.

> No sooner had I found the "treasure island" than I was driven away from it by an opposing gale. I saw the promised land, but was not allowed to enter

it. Owing to no fault of mine, two long years were to elapse before I was to see again—in another continent—that wonderful revelation of human malaria in mosquitoes. During all that time my work was to be pirated by foreigners, and the same maladministration which now drove me into the wilderness was to force me finally out of India just when my discovery might have been of real help to swarming and dying millions.

It is just as well that Ronald Ross has recorded in his book the names of some at least of the executive officers who did so much towards the postponement of the investigation of the cause of the disease which was killing millions of patients every year.

Still, the work was progressing, and in 1898 Ross had traced the parasites into the salivary glands of the insect when he was suddenly ordered to Assam, and coupled with his instructions to work at malaria was the command that he should investigate the obscure disease of kala-azar. Ross now decided to leave India a sadly disillusioned man. India had indeed rejected him:

In those days when an officer had been placed on special duty for any purpose and his work was done, orders conveying the thanks of the Government which had employed him were generally issued as some record that his duty had been faithfully performed. I was not so fortunate, and from that day to this have never received any recognition, that I am aware of, from the Government of India or even from

my old service. I have never been consulted even on my own subject by that Government or by the India Office; never placed on any committee connected with it, never asked officially for my advice; never received any Indian honour, honorary promotion, or reward. In 1912 I was advised to ask for one of the small "good service pensions" which were then sometimes given; but science evidently did not count as such, and I was refused. Out of nearly fifty honours bestowed upon me by governments, universities, academies, and societies, only one has ever reached me from India.[1] Indian writers, from G. M. Giles downwards, have generally attributed my work to others; and, much worse than this, have obstinately opposed my methods for the reduction of malaria. In fact, they have never forgiven me—for what I cannot imagine. Probably it was but the sheer ineptitude of the unintellectuals who "despise science"; but, if so, the question remains whether such barbarians are fit to rule so great an empire.

## Other Claimants

As has been hinted, Ross's claim to priority had been challenged, especially by certain Italian men of science. The work was claimed by many as soon as they saw it published, though hitherto these many had repeatedly proved themselves wrong in their attributions of the cause of malaria.

[1] "The Bombay Memorial Prize Medal, Asiatic Society, Bengal, May 20, 1903. I was made Consulting Member, Advisory Board, Indian Research Fund, but I think that I have only been once consulted by it."

The chief claimant was a Roman professor who seems capable of claiming anything, for we have a pretty good summing-up of his career in the criticisms of a colleague and fellow-worker of his, and we can safely leave him at that. Anyone who wishes to be sure of the facts of the priority of Ross's discoveries should consult a paper by Professor Nuttall on this question in the *Q.J.M.S.*, No. clxxv., N.S., May 1901. Professor Nuttall's analysis of the records, for which he quotes not only the year and month, but the day of the month, has been questioned and is fully accepted by Ross. Once having been shown the way, it was easy for the Italians to follow it. No one can truthfully deny the fact that Ross was blazing the trail whilst the others were groping aimlessly in the dense and obscure thicket. But once they found their way to the clear path, they claimed it as their own.

Ross now resigned from the Service. He was financially rather crippled. He and his family had been obliged to spend £500, including steamship fares, in addition to his salary during his service in India. After eighteen years, the pension awarded him by the Government was £292 a year, and he was now offered a lectureship on Tropical Diseases at Liverpool at the princely salary of £250 per annum with a proportion of the students' fees. He accepted this post, gave up microscopy, and now developed most successfully his scheme for sanitation. He visited time after time malarious districts on the West Coast of Africa, Greece, Spain, Cyprus, Egypt, and

elsewhere, and in each region did much for the health of the people.

He has indeed received certain Imperial awards, and he was also awarded the Nobel Prize for Medicine, but his work in the relief of suffering, in the abolition of a most weakening disease, and even of death, is at least comparable with that of Jenner, Pasteur, Lister, Bruce, Banting, and others. Some of these received a sum of money which placed them beyond anxiety.

As Ross said (writing of Reed, who fell a voluntary victim to yellow fever and so died, apprehensive as to the future of his wife and daughter):

> If I were a millionaire, I should give my money not to institutions, academies, universities, but to men like Reed, in order to make them independent for life. Those who have actually won decisive scientific victories in the past, know best how to win similar victories in the future. But they must be guarded against the scientific middleman, the managing committee, and the educational company-promoters, who are often to-day the parasites and exploiters of talent. They should be free to work where and how they will.

This is a long book, but not too long. It is pleasantly written, and although there are passages here and there one regrets, yet one must make all allowances for a man who has spent a third of his life in the tropics, often in malarial regions. Ross had exhausted himself in fighting official inertia

and in defending the priority of his world-important researches. He knew, more than anyone, the value of his discoveries to suffering humanity, and he had been embittered by the fact that so little help has been afforded him in clearing up the malarial regions of this earth.

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THE END